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THE MOISTURE RE-SORPTION CHARACTERISTICS OF THERMALLY DRIED COAL

Final Report
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Gentlemen,

The Moisture Resorption Characteristics of Thermally Dried Coal

We have pleasure in enclosing the original and 3 bound copies of the Final Report on this project.

Yours Sincerely,

COAL MINING RESEARCH COMPANY

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SUMMARY

The moisture re-adsorption characteristics of thermally dried coal were studied by methods which allowed for using normal commercial size consist samples. Two representative western Canadian coals were used in the study:

- high volatile bituminous C thermal coal
- medium volatile bituminous metallurgical coal

Washed coal samples were taken from the thermal dryer feeds. They were dried in a pilot plant using a batch Roto-Louvre unit so that a wide range of product moisture contents could be obtained by the commercial method of drying.

These coal samples, together with control samples from the full scale drying operations, were exposed to controlled atmospheres in an environmental chamber.

The atmospheric conditions to which the coals samples were subjected were varied between 20 and 40°C and between 30 and 90% relative humidity. The coal samples tested included product dried to as much as 5% below the equilibrium moisture content in addition to current commercial specifications.

At a given temperature and relative humidity the test samples of the high volatile C bituminous coal took more time to attain moisture equilibrium than the test sample of medium volatile bituminous coal. The test results indicated that the coalification process of these two coals has advanced so far that the coal network does not interact with the moisture content in the pore structure.

The wide range of conditions encountered by the coal samples did not alter the moisture level which each coal, however dried, attained when exposed to a given atmosphere for long enough to obtain equilibrium. Hence moisture re-adsorption is not a limiting factor in the drying of coals to low moisture levels provided that prolonged exposure to adverse atmospheric conditions is avoided.

1. INTRODUCTION

Water plays a number of important roles in the formation and utilization of coal.

The Coalification Process

The first stage in the formation of a coal deposit is the accumulation of vegetable matter in swamps. Consolidation and partial decay of this organic material results in peat, which has an in-situ water or moisture content of 90 -80%. The subsequent process, often called coalification, gives rise to brown coals or lignites with progressively lower moisture contents through the range 70 to 30%, and subbituminous coals with moisture contents further reduced towards 12%. The latter stages of coalification result in hard or bituminous coals with 12% and less, and finally anthracites with around 1% moisture content. Thus elimination of water is an integral part of the coalification process. The primary result of its elimination is the obvious increase in the heating value of unit weight of the fuel.

Equilibrium Moisture Content and Surface Moisture Content

The water content referred to above is technically known as the bed moisture or equilibrium moisture content of the coal. At this moisture level the coal in fact appears dry. The as mined coal may also have a few percentage points of moisture on the surface of the particles either as a result of wet conditions in the mine - the coal seam is frequently an acquifer - or from the use of water sprays to control dust.

The beneficiation, or cleaning (removal of high mineral matter content refuse particles), of coal is usually achieved by separations in water based media. This further wets the coal surface. Mechanical dewatering is the final stage of processing in many coalfields, giving, a product with between two and five percent surface moisture content in addition to its inherent, or equilibrium moisture..

Thermal Drying of Coal

In western Canada there are two major disadvantages of such products. Firstly the coal, typically having an abnormally high fines content, would be at or above a five percent surface moisture content level and likely to freeze into huge blocks during winter storage and shipment. Secondly the long distances between the producers and consumers result in high transport costs. Thermal drying is widely practiced to reduce these costs.

There is considerable commercial interest in drying lower rank coals to below their equilibrium moisture content to further enhance product calorific value.

Utilization of Coal

In the carbonization process the moisture contained in the coal results in a toxic effluent. In combustion the moisture has to be evaporated and discharged with the flue gases: thus a higher moisture content product lower furnace efficiency. There are other advantages of lower moisture content coal, such as easier handling, crushing and milling in the feed systems.

The Structure of Coal and Moisture Release by Drying

All coals are considered to be like colloidal gels[1-7], i.e. they consist of a continuous pore system intermeshing with a continuous solid coal network on such a fine scale that the resultant interfacial surface area has a large effect on the physical properties. Since this type of structure was formed by the coal gradually polymerizing out of original peat bog, the prestructure was originally filled with an aqueous medium.

In brown coals the coalification process has not advanced very far and the aqueous medium is still present in the pores. In fact it is still in a state of active interaction with the solid coal substance so that when saturated brown coals are

dried the whole structure collapses. This leads to a reduced particle volume, with the final empty pore volume being considerably less than the original volume of pores filled with water[5]. When this type of dried coal is re-exposed to water it swells but does not regain its original volume.

In high rank bituminous coals the polymerization process has advanced so far that the coal network has become rigid and no longer interacts with any water remaining in the pores. Therefore, when saturated high rank bituminous coals are dried, the porosity remains virtually unaltered, and the previously water-filled pores are occupied by air.

Limits to Thermal Drying of Coal

Practically it has been shown that coals can be thermally dried to several percentage points below their equilibrium moisture content. However, practical problems need to be solved before this method of further upgrading coal can be put to commercial use, including

- the control of product dustiness
- the avoidance of spontaneous combustion
- the safe and efficient storage and handling of the product

This study addresses a further question: the extent of moisture sorption by thermally dried coal from its surrounding atmosphere.

2. BACKGROUND

Trends in the moisture adsorption/desorption behavior of low-rank coals have been studied by many researchers[1-7]. It has been reported that during thermal drying coal goes through physical and chemical changes and pore volume and surface area are reduced. These changes are confirmed by studying the water sorption properties of fresh and dried coal[8-12]. Typically the moisture content of the coal has been shown to be a function of the relative vapour pressure of water (relative humidity) usually at a temperature close to ambient. Isotherms have been determined by equilibrating the moisture content of small amounts of pulverized coal samples in controlled humidities, as in classic studies of Gauger[13], or by the vacuum micro balance technique by Allardice and Evans[5,6], Mahajan and Walker[14], and Yousef[7], where the water vapour pressure is increased or decreased in stages, and equilibrium mass of sorbed water is measured directly at each point.

Figure 2.1 illustrates a typical desorption and re-adsorption isotherm of brown coal[5] at 30°C. An important feature of this isotherm is the strong hysteresis between desorption and re-adsorption curves. It has been reported that pore volume and surface area are reduced during the process of moisture reduction and the coal goes through physical and chemical changes, depending upon the rank of coal and level of moisture reduction[8,9].

The above mentioned micro-studies were conducted on pulverized test samples. The overall process of moisture adsorption/desorption depends on size consist, therefore sorption characteristics of a commercially dried product cannot be predicted from the available data.

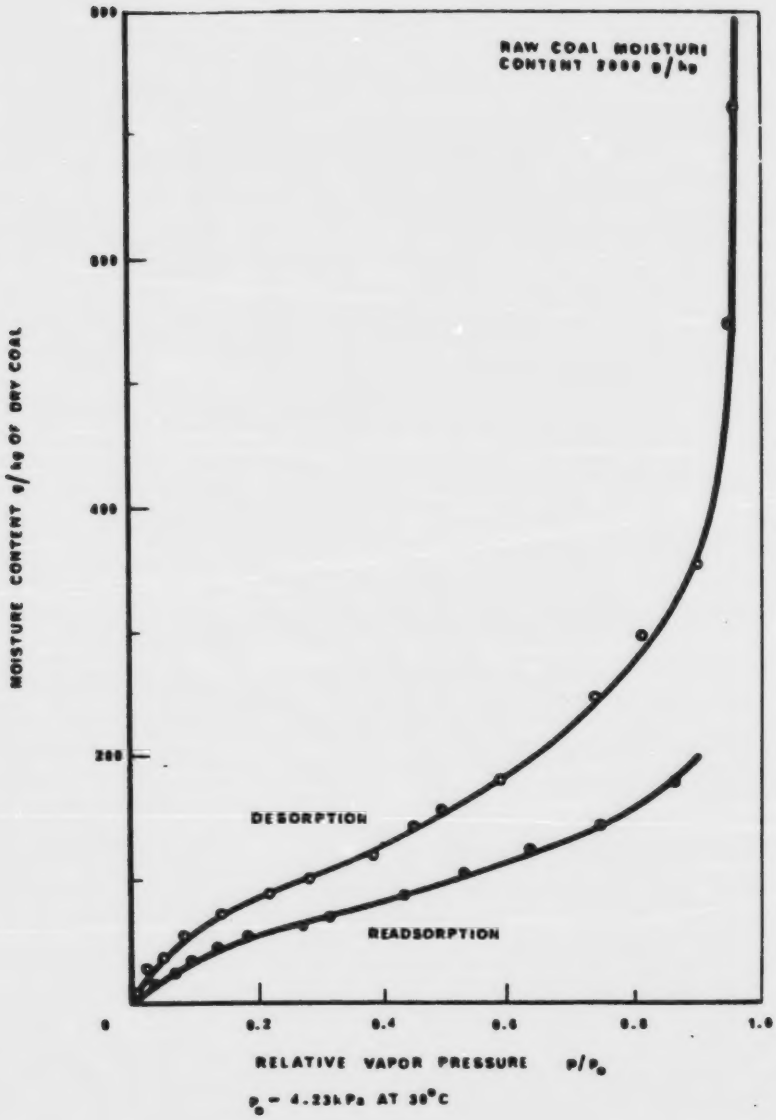


Figure 2.1

WATER SORPTION ISOTHERM ON YALLOURN COAL AT 30°C (Ref.5)

- o Desorption from Bed-Moist State
- • Readsorption

3. OBJECTIVES

The methods of this present study were: to dry representative portions of two commercially cleaned coals to different levels of moisture content under conditions equivalent to commercial coal dryers, and to study moisture sorption characteristics of these dried test samples by equilibrating them under a range of atmospheric conditions.

The project data will be useful to coal producers for optimization of the coal drying process and to predict the stability of the dried coals at given relative humidity and temperature conditions.

The specific objectives of this study program were:

1. To determine the potential of thermally dried coal qualities to adsorb atmospheric moisture.
2. To examine whether there is an optimum moisture level below which there is no ultimate benefit in drying the coal.

4. STUDY OUTLINE AND SAMPLING

4.1 Coal Selection

Two coals were selected for the study in Consultation with the Scientific Officer. These were

Coal A - a high volatile C bituminous thermal coal from an Alberta foothills operation. This coal is normally dried to about 8% total moisture content for shipment to Ontario Hydro

Coal B - a medium volatile bituminous metallurgical coal from an Alberta mountains operation. This coal is normally dried to about 6% total moisture content for shipment to Pacific Rim customers

4.2 Bulk Sample Collection

Four bulk samples were obtained:

A_w, B_w - the commercially cleaned (washed) coals from the dryer feed conveyors

A_d, B_d - the commercially dried products

4.3 Bulk Sample Characterization

A representative portion of each of the bulk samples A_w, A_d, B_w and B_d was separated for laboratory analyses. Each sub-sample was analysed for total moisture content, ash content, volatile matter, calorific value, free swelling index and size consist.

The results of the tests given in Table 4.1 and size consists given in Tables 6.2 and

Table 4.1

ANALYSES OF THE BULK COMMERCIAL COAL SAMPLES
COLLECTED FOR THE STUDY PROGRAM

Sample I.D.	A_w^*		$A_d^\dagger$		B_d			
	Dryer Feed		Dryer Product		Dryer Feed		Dryer Product	
Results	Plant Lab.	CMRC Lab.	Plant Lab.	CMRC Lab.	Plant Lab.	CMRC Lab.	Plant Lab.	CMRC Lab.
% Moisture, M_{ar}	14(avg.)	13.68	7.96	7.54	-	12.26	5.60	5.55
% Ash (d)	-	11.79	11.87	12.46	-	10.51	10.75	10.76
% V.M. (d)	-	32.84	35.23	32.70	-	20.06	22.75	19.93
C.V. cal/g dry basis	-	6596	6638	6519	-	7768	-	7735
FSI	-	0	-	0	-	5.50	-	5.50
Equilib. Moisture	-	8.66	9 - 10	8.55	-	1.45	-	1.54

* High Volatile C Bituminous Coal, Alberta Foothills
Sample collected on January 15, 1985
Dryer Data
Dryer Feed Rate 1325 Tonnes/hr
Exhaust Gas Temperature 135°C
Target Product Moisture 8½ - 9% as received basis

Medium Volatile Bituminous Coal, Alberta Mountains
Samples collected on January 14, 1985
Dryer Data
Dryer Feed Rate 560 Tonnes/hr
Exhaust Gas Temperature 125°C
Target Product Moisture 6- 7% as received basis

ar As received basis

(d) dry-weight basis

6.3 agreed with the average results reported by the quality control laboratories of the coal producers and thus confirmed the representativeness of each material collected for the study program.

4.4 Study Product Specifications

Coal A, having an equilibrium moisture content of approximately 9.5%, was to be studied at three levels of moisture content designated:

A_{w+1} = (Equilibrium Moisture Content + 1)% moisture
A_{w-2} = (Equilibrium Moisture Content - 2)% moisture
A_{w-5} = (Equilibrium Moisture Content - 5)% moisture

Coal B, having and equilibrium moisture content of approximately 2.0%, was to be studied for moisture sorption using product at three levels of moisture content similarly designated:

B_{w+5} = (Equilibrium Moisture Content + 5)% moisture
B_{w+2} = (Equilibrium Moisture Content + 2)% moisture
B_{w-1} = (Equilibrium Moisture Content - 1)% moisture

4.5 Bulk Drying and Received Samples

Section 5 of this report describes how batches of the bulk washed coal samples A_w and B_w were dried to obtain product equivalent to that which would be obtained from commercial operations set to meet the above designated specifications. In addition to these test samples produced in CMRC's Pilot Plant it was agreed to run tests on the as received commercially dried samples A_w, B_w, A_d and B_d.

4.6 Moisture Sorption Study

Sections 6, 7 and 8 of this report describe how the tests were run on the eight product coals, each being observed for moisture adsorption/desorption over a wide range of relative humidity and at three levels of atmospheric temperature.

5. BATCH DRYING

The objective was to produce alternative commercial dried products by drying representative portions of cleaned coals A_w and B_w for the proposed moisture sorption study.

Before starting with actual drying tests it is necessary to develop "drying curves" which show the time dependence of moisture content as it is reduced by simultaneous mass and heat transfer between coal and the drying medium during drying in a batch dryer. From the drying curve a residence time is determined for the target product moisture.

5.1 Bench Scale Batch Roto-Louvre Dryer

Figure 5.1 shows the Bench Scale Batch Roto-Louvre Dryer used for batch drying the representative portions of the coals A_w and B_w to obtain the test samples for moisture sorption study program. The major components of the drying system are described below.

5.1.1 Dryer Drum

The dryer drum is designed to handle a batch of 10 kilograms of 25 mm x 0 size consist coal. The entire unit rotates on two pillow block bearings. The drying medium (hot air) enters through two air distribution areas or dampers, passes into the drying chamber by means of the louvres, and then flows through the drying coal bed. The flow is evenly distributed by adjusting the dampers.

5.1.2 Dryer Drive

The rotation of the dryer drum is adjusted by the dryer drive. The angle of repose is adjusted to get maximum efficiency of the system.

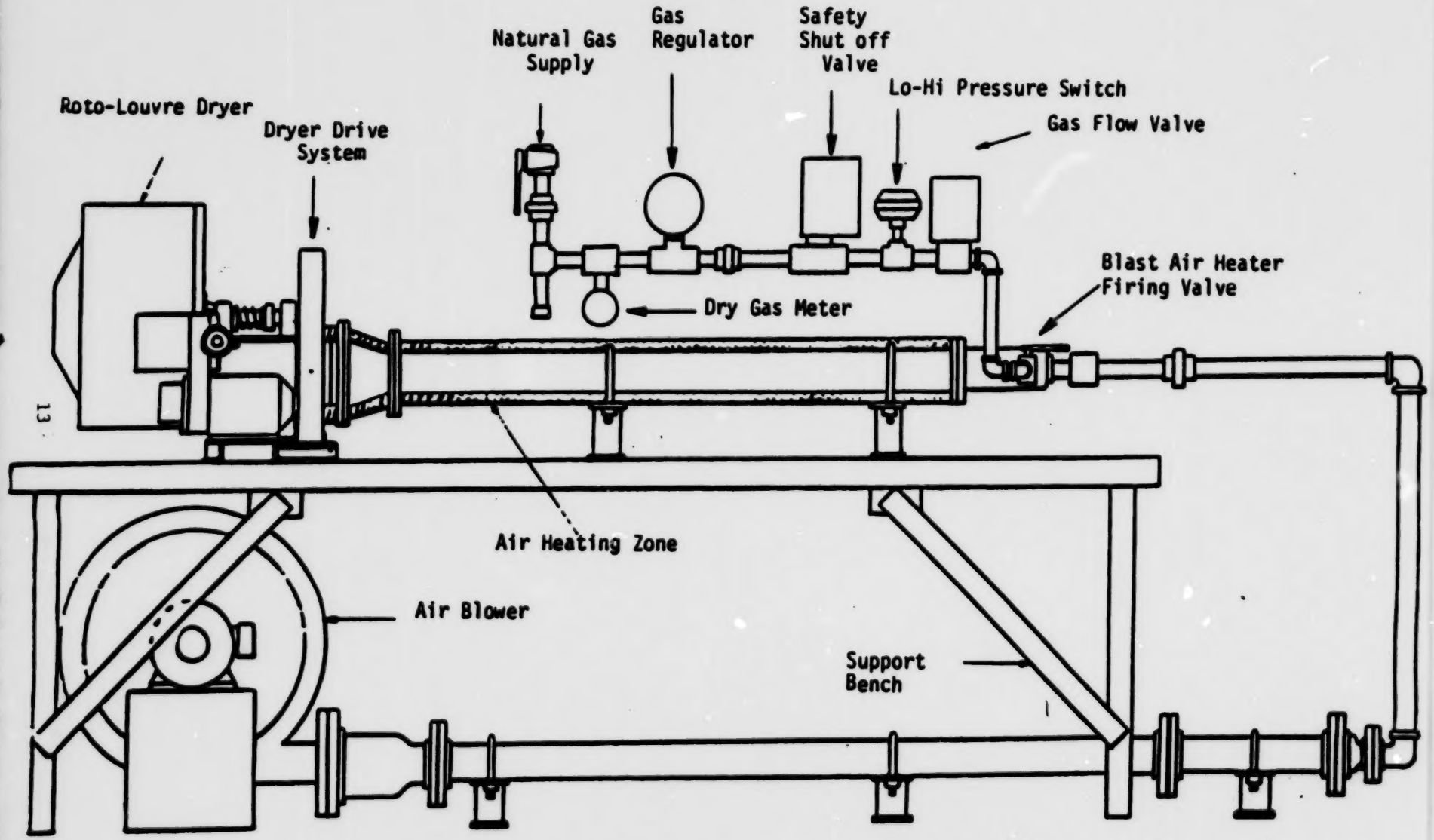


Figure 5.1 CMRC BENCH SCALE BATCH ROTO-LOUVRE DRYER

5.1.3 Air Blower

The Eclipse "SM" series blower has a 3 H.P. motor and can deliver a maximum 12 m^3 per minute of air at ambient conditions.

5.1.4 Eclipse Thermal Bast Heater

The thermal blast heater produces from 1.5 to 11.5 m^3 per minute of heated air with a temperature rise from 150 to 875°C at a pressure of 0.35 MPa. This is equivalent to heat release of 36,000 kJ to 190,000 kJ per hour. The air flow is regulated to get minimum (less than 1%) loss of fine particles during a drying test run. The flow of natural gas is regulated by the controls to maintain drying medium temperature constant.

5.2 Drying Curves

After adjusting the drying conditions and stabilizing the drying system, an 8 kg coal sample was poured into the dryer drum. Monitoring of coal and exhaust gas temperatures began immediately. Small grab samples (100 g) of the coal being dried were taken at one minute intervals during the drying period. Each grab sample was immediately sealed in an air-tight glass jar. After completion of the drying test run the remaining coal was removed from the drum and stored in a plastic pail until required for subsequent laboratory analyses. The glass jars containing the grab samples from the drying test run were cooled to ambient temperature. The coal sample from each jar was transferred to a pre-weighed petri-dish, weighed with the petri-dish, placed in an oven regulated at 105°C, dried, and reweighed after cooling. The total moisture content of each grab sample was then determined.

Experimental details and data collected during these batch drying tests of the coals A_W and B_W are given in Tables 5.1 and 5.2. Figures 5.2 and 5.3 are the drying curves of these coals.

Table 5.1

BATCH DRYING TEST DATA OF HIGH VOLATILE C BITUMINOUS COAL

Drying Conditions

Unit	Bench Scale Batch Roto-Louvre Dryer
Material	8 kg Coal A_w
Drying Medium Temperature	350°C
Air Flow Rate	40 m^3/h
Gas Flow Rate	0.58 m^3/h

DRYING DATA

Drying Time min.	Material Temperature °C	Exhaust Gases Temperature °C	Remaining Moisture* % M_{ad}	% M_d
0	22	-	12.03	13.68
1	43	53	11.67	13.21
2	53	63	10.86	12.18
3	57	70	9.73	10.78
4	59	70	8.80	9.65
5	61	70	7.83	8.50
6	62	71	7.06	7.59
7	65	73	6.26	6.68
8	71	75	5.44	5.75
9	76	77	5.21	5.00
10	80	80	4.30	4.49
11	83	84	3.85	4.00
12	86	88	3.48	3.60
13	88	90	3.15	3.25

* % M_{ad} % Moisture - wet weight basis

% M_d % Moisture - dry weight basis

Figure 5.2 MOISTURE AND TEMPERATURE DRYING CURVES OF HIGH VOLATILE C BITUMINOUS COAL

Unit Bench Scale Batch Roto-Louvre Dryer
Material 8 kg coal A_w
Drying Medium Temperature, 350°C

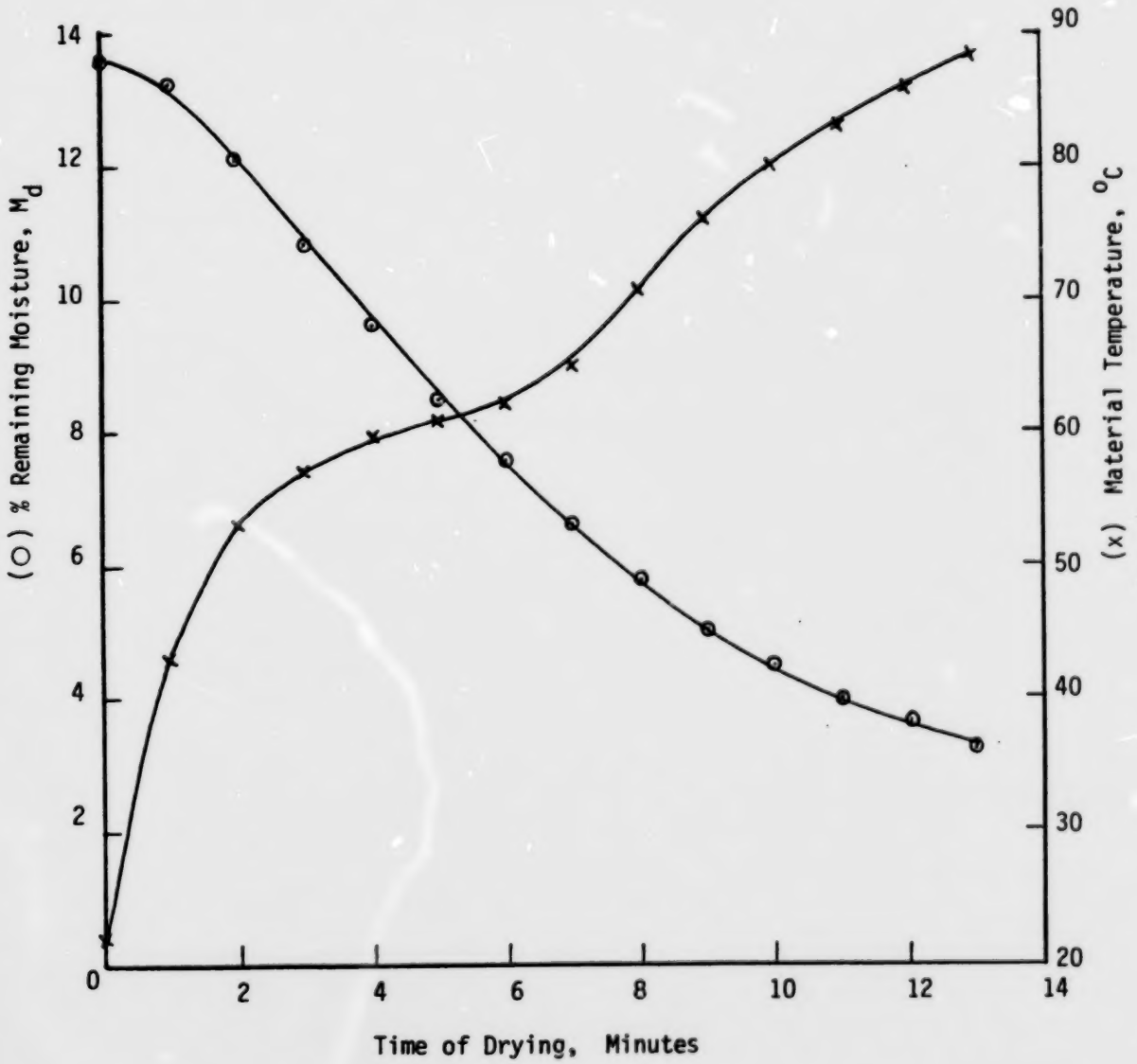


Table 5.2

BATCH DRYING TEST DATA OF MEDIUM VOLATILE BITUMINOUS COAL

Drying Conditions

Unit	Bench Scale Batch Roto-Louvre Dryer
Material	8 kg Coal A_w
Drying Medium Temperature	350°C
Air Flow Rate	40 m^3/h
Gas Flow Rate	0.58 m^3/h

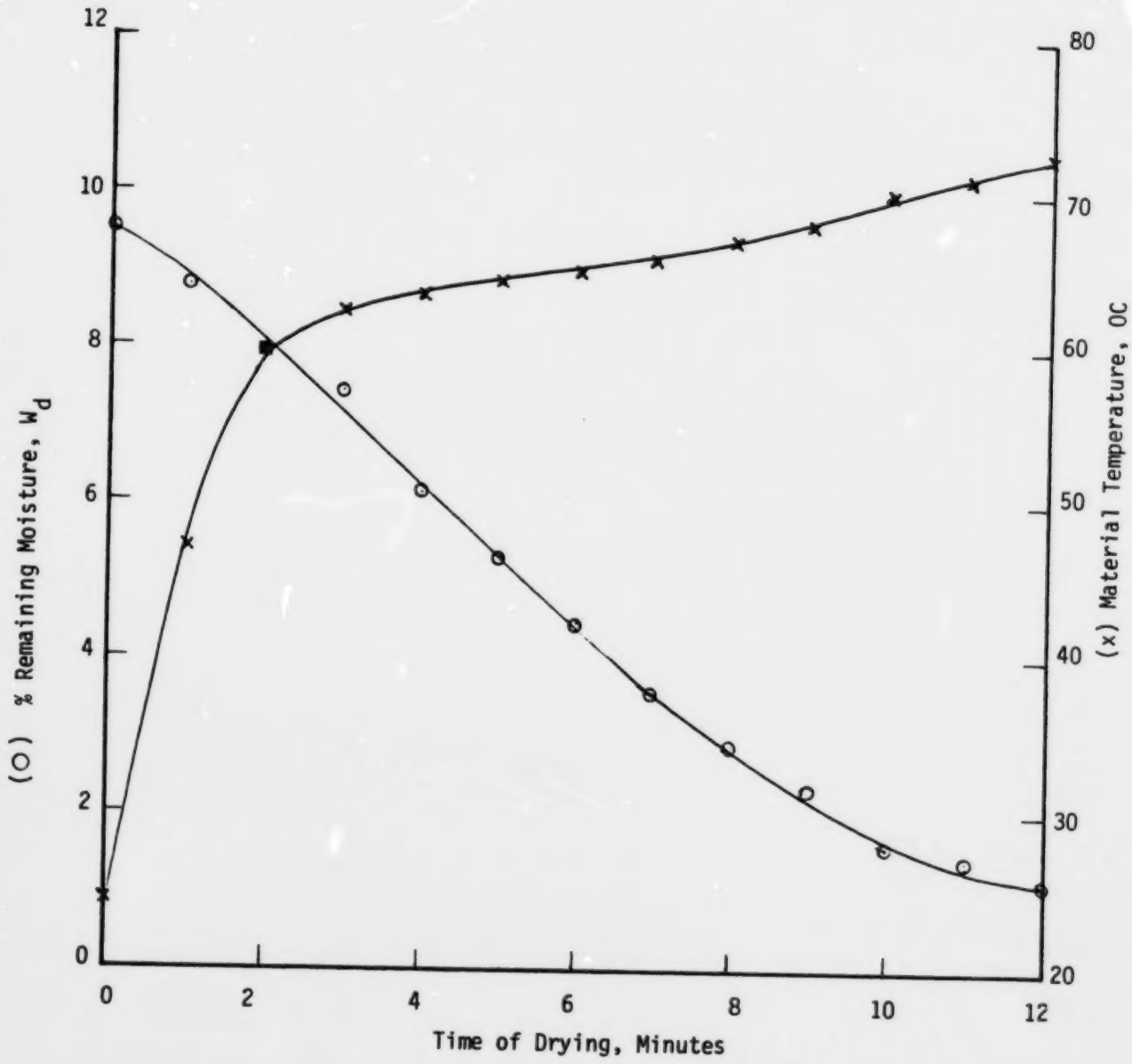
DRYING DATA

Drying Time min.	Material Temperature °C	Exhaust Gases Temperature °C	Remaining Moisture* % M_{ad}	% M_d
0	22	-	8.74	9.58
1	47	54	7.90	8.76
2	59	62	7.32	7.90
3	62	63	6.93	7.45
4	63	64	5.94	6.12
5	64	65	5.02	5.29
6	65	66	4.29	4.48
7	66	66	3.41	3.53
8	67	67	2.72	2.80
9	68	67	2.22	2.27
10	70	67	1.65	1.68
11	70	71	1.36	1.39
12	72	73	1.09	1.10

* % M_{ad} % Moisture - wet weight basis

% M_d % Moisture - dry weight basis

Figure 5.3 MOISTURE AND TEMPERATURE DRYING CURVES OF MEDIUM VOLATILE BITUMINOUS COAL
Dryer Bench Scale Batch Roto-Louvre
Material 8 kg coal B_w
Drying Medium Temperature, 350°C



6. PREPARATION OF TEST SAMPLES FOR MOISTURE SORPTION STUDY

Moisture sorption was to be studied at three temperature levels; thus three sets of test samples had to be prepared for each coal. Since the capacity of the batch pilot dryer was limited, three 8kg test samples were separately dried to each specified moisture level.

6.1 Sample Drying

From the drying curves, Figure 5.2 and 5.3, residence times were determined for batch drying to obtain the specified test samples. The dryer was conditioned and each sample was dried for its respective residence time. The dried coal samples were cooled separately in air-tight containers. Table 6.1 contains the residence times and moisture contents of three batch dried sets of test samples and the control samples.

6.2 Characterization of Test Samples

Sub-samples of test samples A_{w+1}, A_{w-2}, A_{w-5}, B_{w+5}, B_{w+2} and B_{w-1} of set #1 were obtained to determine equilibrium moisture content and size consist of each test sample.

6.2.1 Equilibrium Moisture Content

Equilibrium moisture content was determined using ASTM Method D1412 (Appendix 4) . Each prepared sample was equilibrated at 30°C and 96-97% relative humidity for a period of 72 hours. Tables 6.2 and 6.3 contain the average values from duplicate tests.

6.2.2 Size Analysis

Sub-samples of the test samples of set #1 were air dried at room temperature. The size consist of each air-dried sample was determined with a Gilson Screening Test Machine Model TM4. Tables 6.2 and 6.3 contain the size consists of the test samples.

Table 6.1

LIST OF TEST SAMPLES FOR MOISTURE SORPTION STUDY

Sample I.D.	Description of Test Sample	Mean Residence Time for Batch Drying (min.)	% Total Moisture Content M_{ad}		
			Set #1	Set #2	Set #3
A_w	Cleaned high volatile C Bituminous Coal	-	13.68	13.68	13.68
A_d	Commercially Dried Product (Control Sample)	-	7.53	7.31	7.39
A_{w+1}	Equilibrium Moisture +1%	3-4	10.50	10.15	8.80
A_{w-2}	Equilibrium Moisture -2%	6-7	7.41	8.76	6.33
A_{w-5}	Equilibrium Moisture -5%	11-12	4.88	5.81	5.14
B_w	Cleaned Medium Volatile Bituminous Coal	-	12.26	12.26	12.26
B_d	Commercially Dried Product	-	6.13	6.20	6.85
B_{w+5}	Equilibrium Moisture +5%	3-4	7.26	6.66	5.34
B_{w+2}	Equilibrium Moisture +2%	6-7	2.56	4.88	2.38
B_{w-1}	Equilibrium Moisture -1%	13-14	0.59	0.91	0.65

TABLE 6.2

PARTICLE SIZE ANALYSES OF HIGH VOLATILE C BITUMINOUS COAL TEST SAMPLES

Sample I.D.	A_w		A_d		A_{w+1}		A_{w-2}		A_{w-5}	
Equilib. Moisture 96% RHD 30°C	8.66		8.55		8.57		8.50		8.46	
Size Consist (mm)	%	% cum	%	% cum	%	% cum	%	% cum	%	% cum
+ 12.50	8.85	100	9.81	100	10.79	100	11.18	100	10.62	100
12.50 x 6.70	20.15	91.15	19.44	90.19	19.26	89.21	18.54	88.82	18.60	89.38
6.70 x 3.35	18.22	71.00	19.01	70.45	18.20	69.95	17.54	70.28	18.90	70.78
3.35 x 1.70	18.28	52.78	17.44	51.74	16.26	51.15	18.53	52.74	17.24	51.88
1.70 x 0.60	16.28	34.50	15.59	34.30	17.77	34.89	15.48	34.21	18.53	34.64
1.60 x 0.30	10.00	18.22	11.81	18.71	9.81	17.12	9.21	18.73	9.57	16.11
0.30 x 0.15	5.15	8.22	4.29	6.90	4.52	7.31	5.61	9.52	4.42	6.54
-0.15	3.07	3.07	2.61	2.61	2.79	2.79	3.91	3.91	2.12	2.12

TABLE 6.3

PARTICLE SIZE ANALYSES OF MEDIUM VOLATILE BITUMINOUS COAL TEST SAMPLES

Sample I.D.	B_w		B_d		B_{w+5}		B_{w+2}		B_{w-1}	
Equilib. Moisture 96% RHD 30°C	1.45		1.54		1.64		1.64		1.58	
Size Consist (mm)	%	% cum	%	% cum	%	% cum	%	% cum	%	% cum
+ 12.50	7.23	100	5.90	100	4.82	100	4.48	100	5.23	100
12.50 x 6.70 mm	7.76	92.77	8.43	94.10	7.91	95.18	7.14	95.52	7.88	94.77
6.70 x 3.35 mm	10.05	85.01	11.13	85.67	11.04	87.27	9.75	88.38	10.68	86.89
3.35 x 1.70 mm	13.40	74.96	14.84	74.54	14.06	76.23	13.22	78.63	13.64	76.21
1.70 x 0.60 mm	19.75	61.56	21.25	59.70	20.98	62.17	21.62	65.41	21.14	62.57
0.60 x 0.30 mm	14.29	41.81	13.66	38.45	13.43	41.19	14.69	43.79	14.07	41.43
0.30 x 0.15 mm	11.29	27.52	10.96	24.79	12.19	27.76	12.00	29.10	11.66	27.36
+ 0.15 mm	16.23	16.23	13.83	13.83	15.57	15.57	17.10	17.10	15.70	15.70

7. ENVIRONMENTAL CONTROL CHAMBER

Figure 7.1 shows the Precision Environmental control chamber, Model 230, Cat. No. 31975, built by GCA Corporation, Precision Scientific Group, U.S.A. The chamber offers a substantial 3.35 m^3 (36 cubic ft.) of working internal volume. Seven tiers of perforated shelving giving 3.9 m^2 (42 square ft.) total shelf area. The walls are insulated with 9 cm (3.5") thick urethane. The door opening measures 56 cm x 152 cm (22" x 60") with a thermopane type viewing window offering a clear view of the main chamber. The forced air circulation system includes a blower, a heater and an air cooled condenser. This arrangement maintains uniform humidity and temperature throughout the entire chamber; the chamber is equipped with temperature and humidity controllers.

7.1 Temperature Controller

The temperature control panel is shown in Figure 7.2. The desired chamber temperature is set on the wheel switch (C) and is controlled to a tenth of a degree celsius. After attaining the desired temperature the "High Limit Thermostat" (B) and "Low Limit Thermostat" (I) are adjusted to regulate the chamber temperature.

Defrost light (H) glows when the cooling coal is being defrosted. It de-energies when the defrost period ends.

7.2 Humidity Controller

The humidity control panel is shown in Figure 7.3. The humidity is measured and controlled by resistance type sensors. The main components of the control panel are described below.

7.2.1 Relative Humidity Setpoint Knob, E.

Knob E is set to the level of relative humidity (% RH) required within the chamber. The humidity controller adjusts the moisture of the air to maintain the desired relative humidity.

Figure 7.1
ENVIRONMENTAL CONTROL CHAMBER

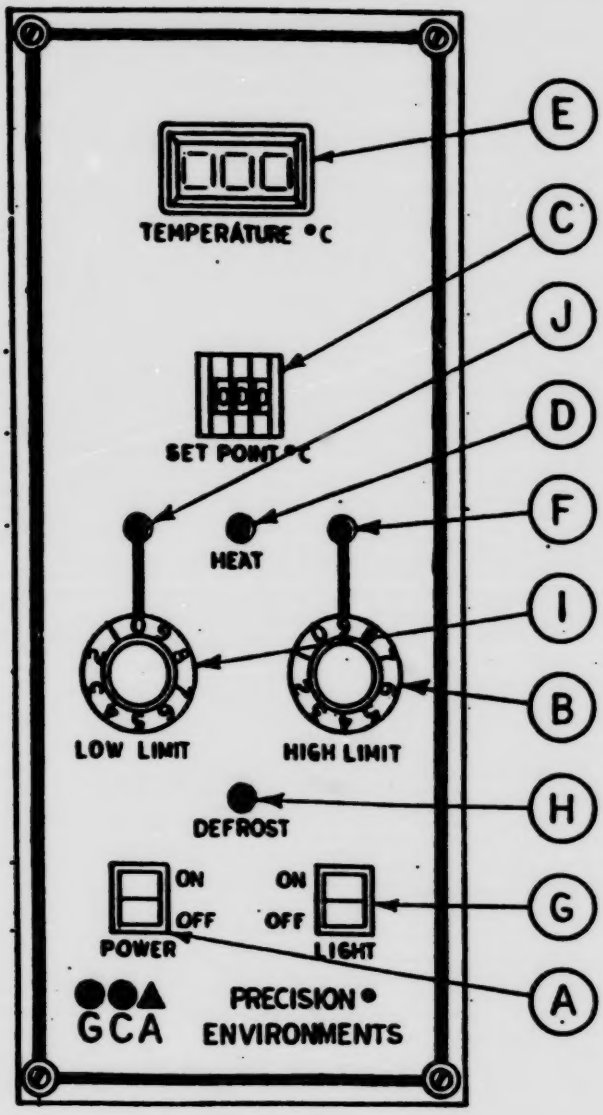


Figure 7.2

TEMPERATURE CONTROL SYSTEM OF THE
ENVIRONMENTAL CONTROL CHAMBER

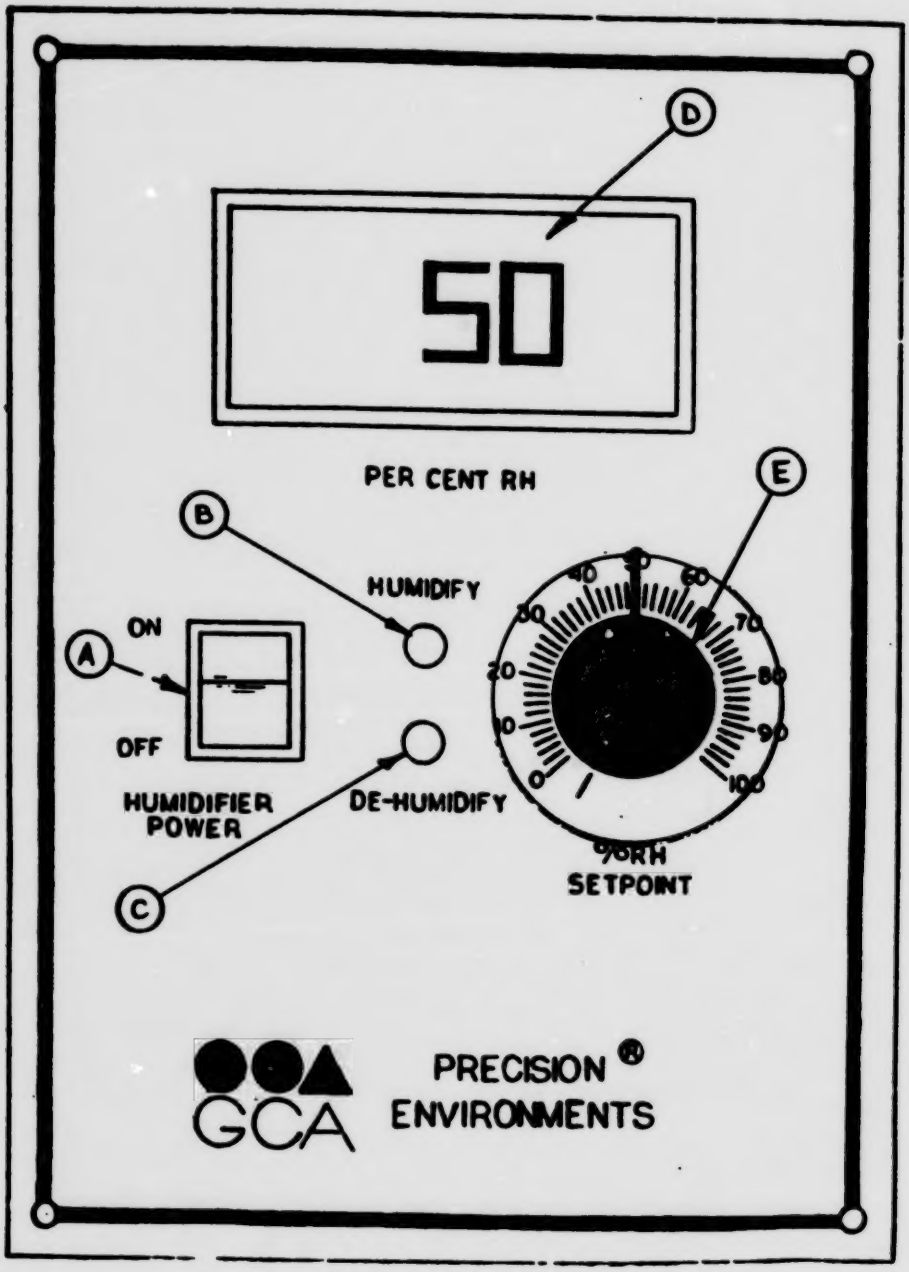


Figure 7.3
HUMIDITY CONTROL SYSTEM OF THE ENVIRONMENTAL CONROL CHAMBER

7.2.2 Humidity Pilot Light, B

This light, B, glows when the humidity controller is adding moisture from the steam generator (not shown) to the chamber.

7.2.3 De-humidity Pilot Light, C

This light, C, glows when the cooling system is removing moisture from the chamber.

7.2.4 Humidity Sensor (not shown)

Located within the chamber the humidity sensor consists of two temperature sensors, one dry and one kept moist by a "sock" partially immersed in a jar of water.

7.3 Performance of the Environmental Chamber

Before starting with the moisture sorption tests the performance of the temperature and relative humidity control systems were checked. The readings of relative humidity indicated by the digital read-out of the unit at different set points were compared with the readings indicated by the precalibrated hygrometer (Model H.L. 240D, Lee Dickens Limited, England). At any given relative humidity between 30% and 90% the difference was less than 5%.

At the temperature setpoints of 10°C, 20°C, 30°C, and 40°C the relative humidity was adjusted between 30% and 90%. At a 10°C set point and at relative humidities betweeen 70% and 90% the cooling system of the environmental chamber could not maintain a constant temperature. At the temperature setpoints of 20°C, 30°C and 40°C the temperature remained constant with a relative humidity variation within the chamber between 30% and 90%.

8. MOISTURE SORPTION TESTS

Moisture sorption tests were conducted at 20°C, 30°C and 40°C. A new set of eight test samples was used for each temperature.

8.1 Test Procedure

8.1.1 Moisture Sorption Tests at 20°C

The temperature controls on the environmental chamber were adjusted to maintain a 20°C temperature in the chamber. The temperature was checked at different locations inside the chamber. When a uniform chamber temperature was attained the steam generator for the humidity control system was started and the controls were adjusted to obtain 88% relative humidity in the chamber. The relative humidity fluctuated between $\pm$ 5% of the set-point due to the intermittent steam injection cycle of the humidity control system. The chamber was allowed to stabilize for about four hours.

Exact amounts (4 to 5 kg) of the test samples set #1

A_d, A_{w+1}, A_{w-2}, A_{w-5}, B_d, B_{w+5}, B_{w+2}, and B_{w-1}

were weighed and trays containing the evenly spread test samples were placed in the chamber. The weight lost or gained by each sample was recorded, daily. The test samples of high volatile C bituminous coal took longer to attain sorption equilibrium compared to the test samples of medium volatile bituminous coal. After reaching equilibrium at 20°C and 88% relative humidity the weights of the test samples were recorded.

The chamber was adjusted to 80% relative humidity . The weights were again recorded until the test samples attained sorption equilibrium.

The observations were repeated at 50%, 40%, and 30% relative humidities.

8.1.2 Moisture Sorption Tests at 30°C

The environmental chamber was stabilized at 30°C and 88% relative humidity as discussed earlier in the section 8.1.1.

Weighed amounts of the eight new test samples (set #2) were placed in the environmental chamber. The weights of the test samples were recorded after attaining sorption equilibrium at 88%, 80%, 70%, 60%, 50%, and 30% relative humidities.

8.1.3 Moisture Sorption Tests at 40°C

The environmental chamber was stabilized at 40°C and 88% relative humidity. A new set of eight samples (set #3) were used and the weights of the test sample after attaining sorption equilibrium at 88%, 70%, 50%, 40% and 30% relative humidities.

8.2 Test Results

The results of all tests completed at 20°C, 30°C and 40°C are given in Tables 8.1 and 8.2 and graphically presented in Figures 8.1 to 8.14.

Table 8.1

MOISTURE SORPTION CHARACTERISTICS OF A HIGH VOLATILE C BITUMINOUS COAL FROM ALBERTA FOOTHILLS AT DIFFERENT TEMPERATURES AND RELATIVE HUMIDITIES

Sample I.D.	A_d			A_{w+1}			A_{w-2}			A_{w-5}		
Temp. °C	20	30	40	20	30	40	20	30	40	20	30	40
% RH	% Moisture Content (Wet Weight Basis)											
88	7.82	7.89	7.42	7.66	7.96	7.77	7.79	7.88	7.50	7.50	7.73	7.77
80	7.53	7.71	-	7.36	7.77	-	7.41	7.66	-	7.03	7.57	-
70	7.24	7.36	6.77	7.17	7.44	7.04	7.31	7.34	6.91	6.66	7.28	7.17
60	-	6.92	6.32	-	7.01	6.58	-	6.91	6.42	-	6.89	6.83
50	6.39	6.41	5.68	6.27	6.51	5.91	6.45	6.38	5.90	6.31	6.40	6.23
40	-	-	4.97	-	-	5.18	-	-	5.16	-	-	5.33
30	5.59	4.97	4.53	5.43	5.02	4.73	5.62	4.95	4.80	5.59	5.06	4.92

Table 8.2

MOISTURE SORPTION CHARACTERISTICS MEDIUM VOLATILE
BITUMINOUS COAL OF ALBERTA MOUNTAINS AT DIFFERENT TEMPERATURES AND RELATIVE HUMIDITIES

Sample I.D.	B_d			B_{w+5}			B_{w+2}			B_{w-1}		
Temp. °C	20	30	40	20	30	40	20	30	40	20	30	40
% RH	% Moisture Content (Wet Weight Basis)											
88	1.36	1.52	1.54	1.49	1.48	1.46	1.35	1.45	1.45	1.31	1.49	1.49
80	1.15	1.42	-	1.27	1.37	-	1.15	1.37	-	1.11	1.39	-
70	1.04	1.23	1.24	1.16	1.22	1.13	1.04	1.20	1.10	1.00	1.24	1.20
60	-	1.05	1.09	-	1.09	0.99	-	1.07	0.97	-	1.10	1.07
50	0.70	0.89	0.96	0.90	0.85	0.84	0.83	0.80	0.81	0.76	0.87	0.92
40	-	-	0.82	-	-	0.70	-	-	0.67	-	-	0.80
30	0.57	0.64	0.67	0.69	0.56	0.61	0.59	0.58	0.57	0.60	0.63	0.67

Figure 8.1
Moisture Sorption Characteristics of Test Sample Coal A_d
at Different Temperatures and Relative Humidities

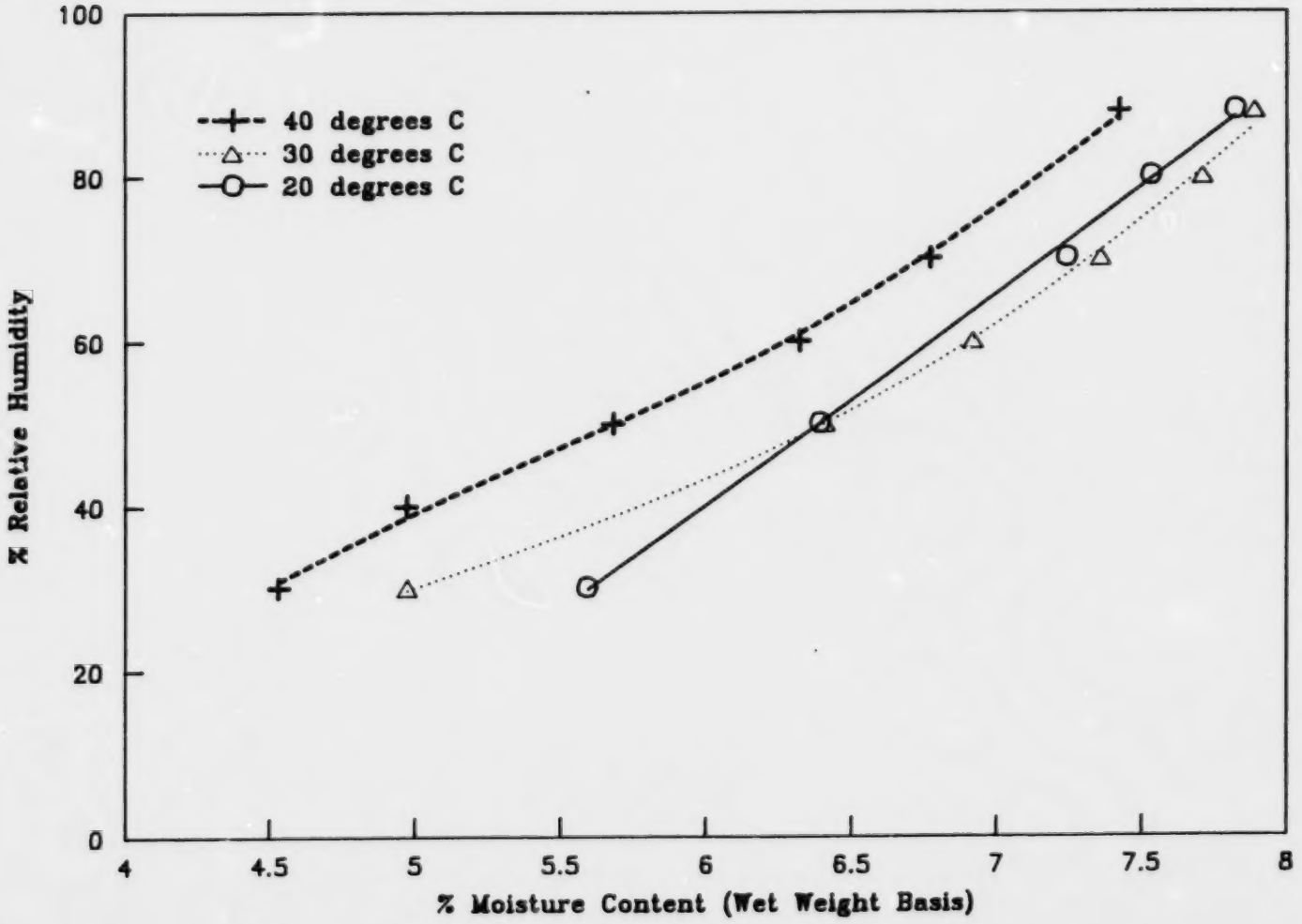


Figure 8.2
Moisture Sorption Characteristics of Test Sample Coal A_{w+1}
at Different Temperatures and Relative Humidities

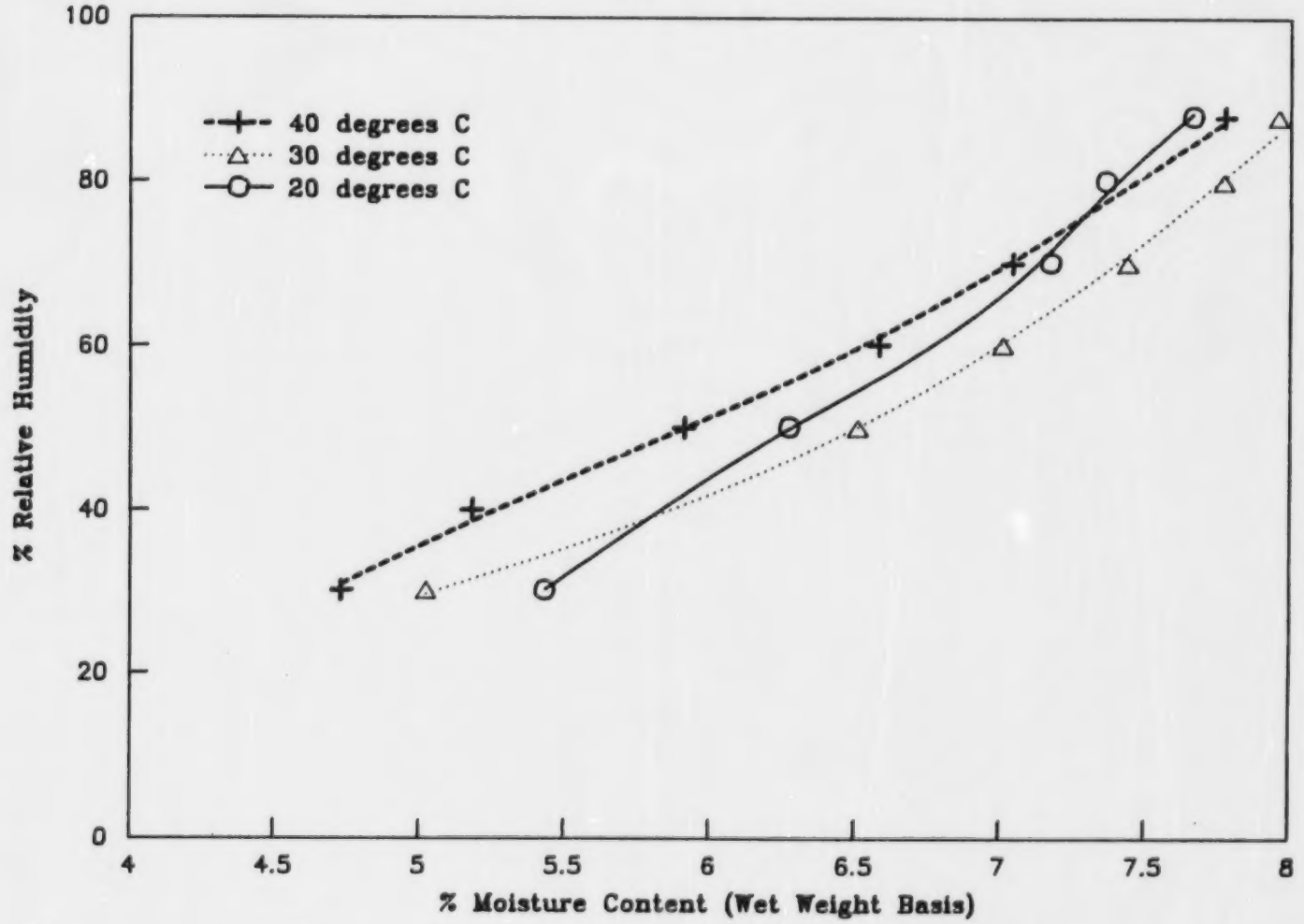


Figure 8.3
Moisture Sorption Characteristics of Test Sample Coal A_{w-2}
at Different Temperatures and Relative Humidities

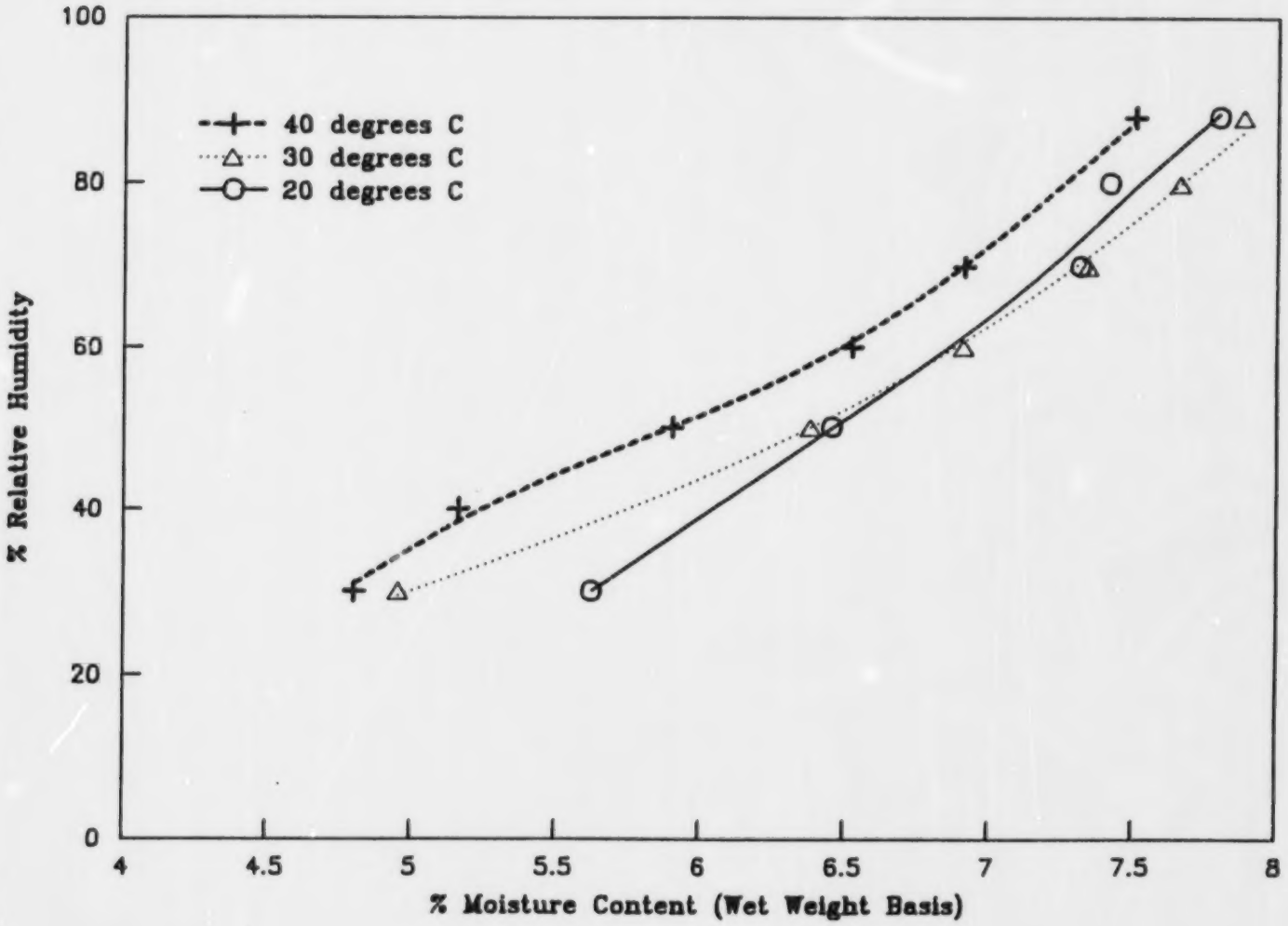


Figure 8.4
Moisture Sorption Characteristics of Test Sample Coal A_{w-5}
at Different Temperatures and Relative Humidities

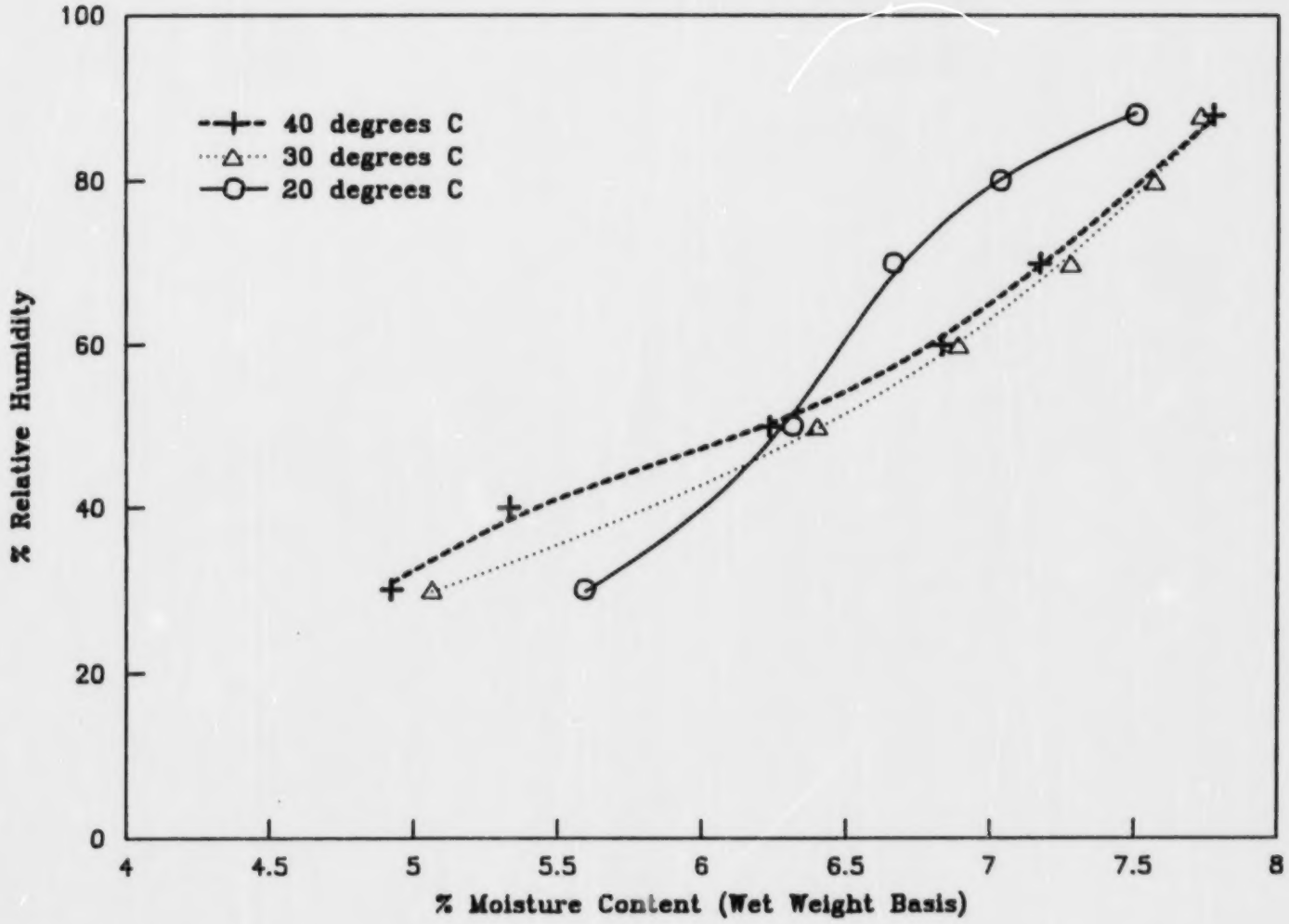


Figure 8.5
Effects of Thermal Drying on Moisture Sorption Characteristics
of High Volatile C Bituminous Coal at 20 ° C

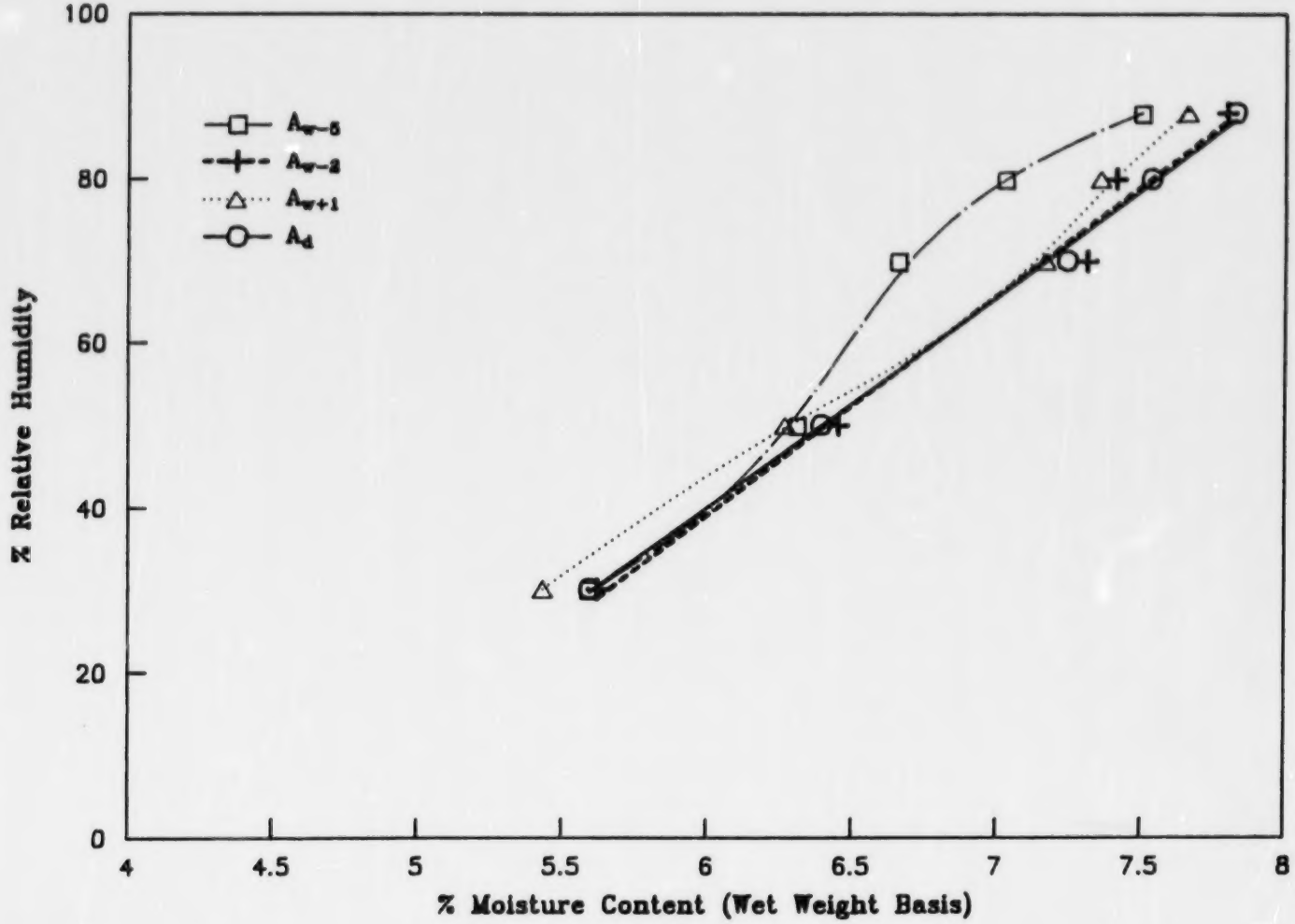


Figure 8.6
Effects of Thermal Drying on Moisture Sorption Characteristics of High Volatile C Bituminous Coal at 30 ° C

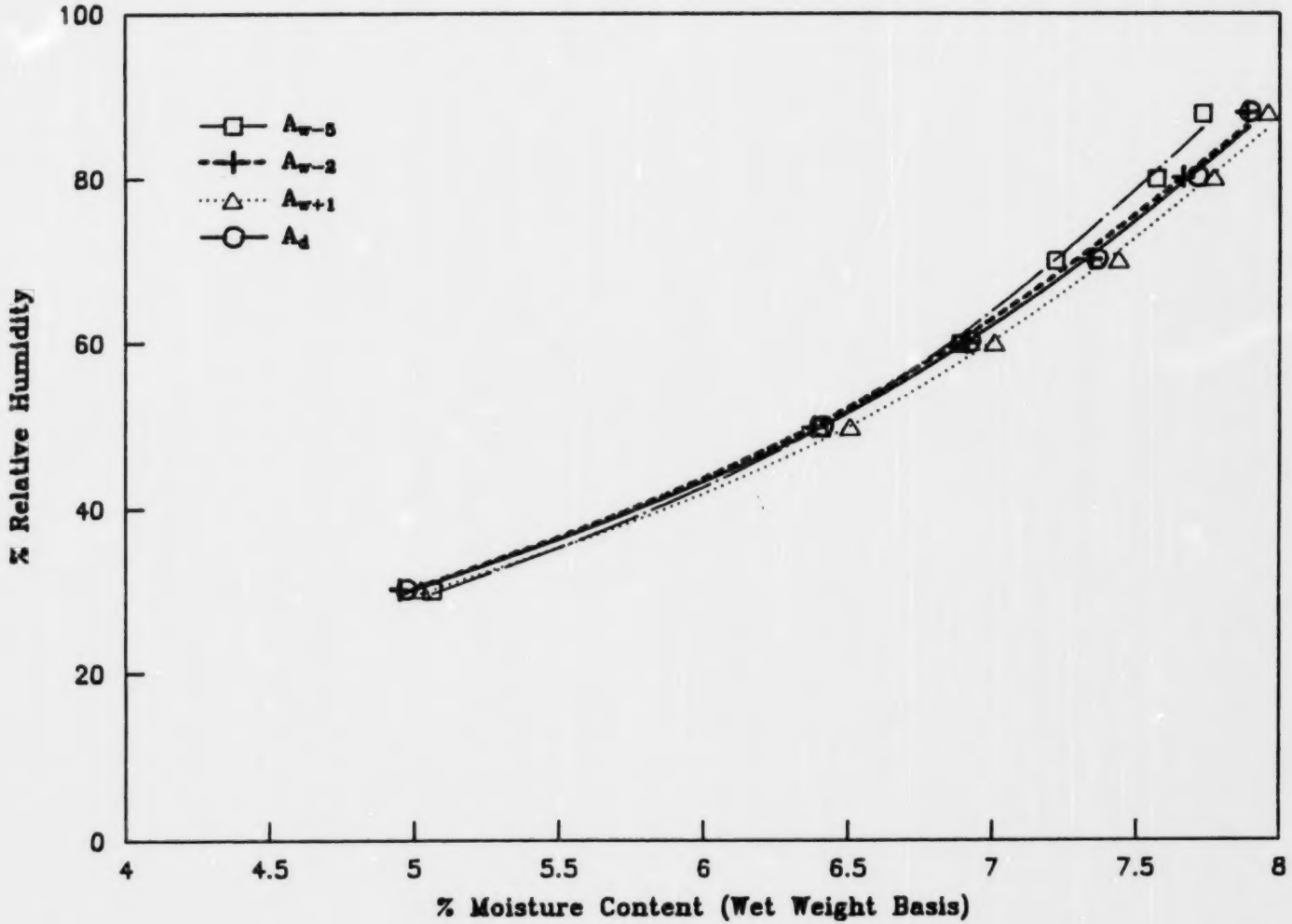


Figure 8.7
Effects of Thermal Drying on Moisture Sorption Characteristics of High Volatile C Bituminous Coal at 40 ° C

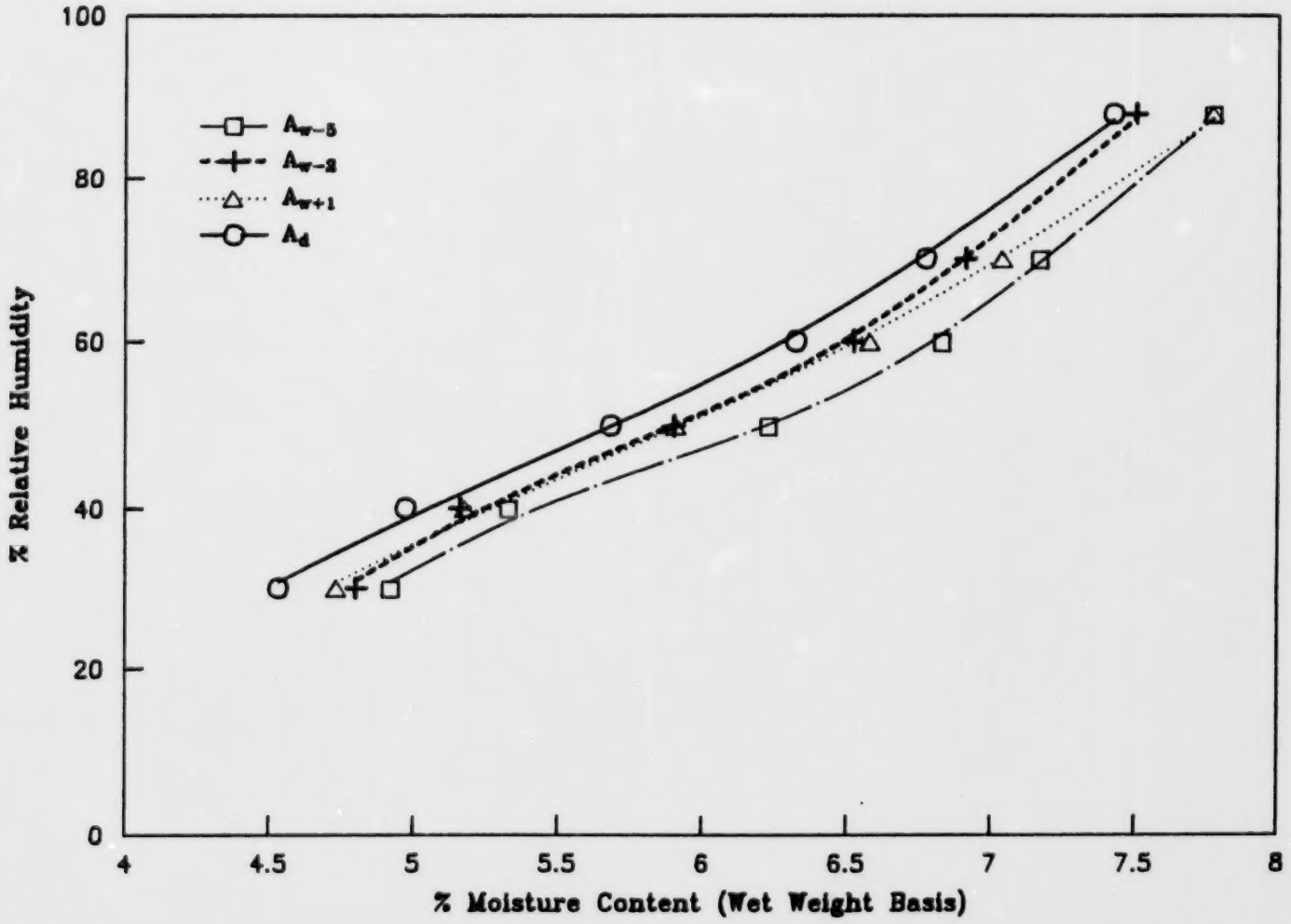


Figure 8.8
Moisture Sorption Characteristics of Test Sample Coal B_d
at Different Temperatures and Relative Humidities

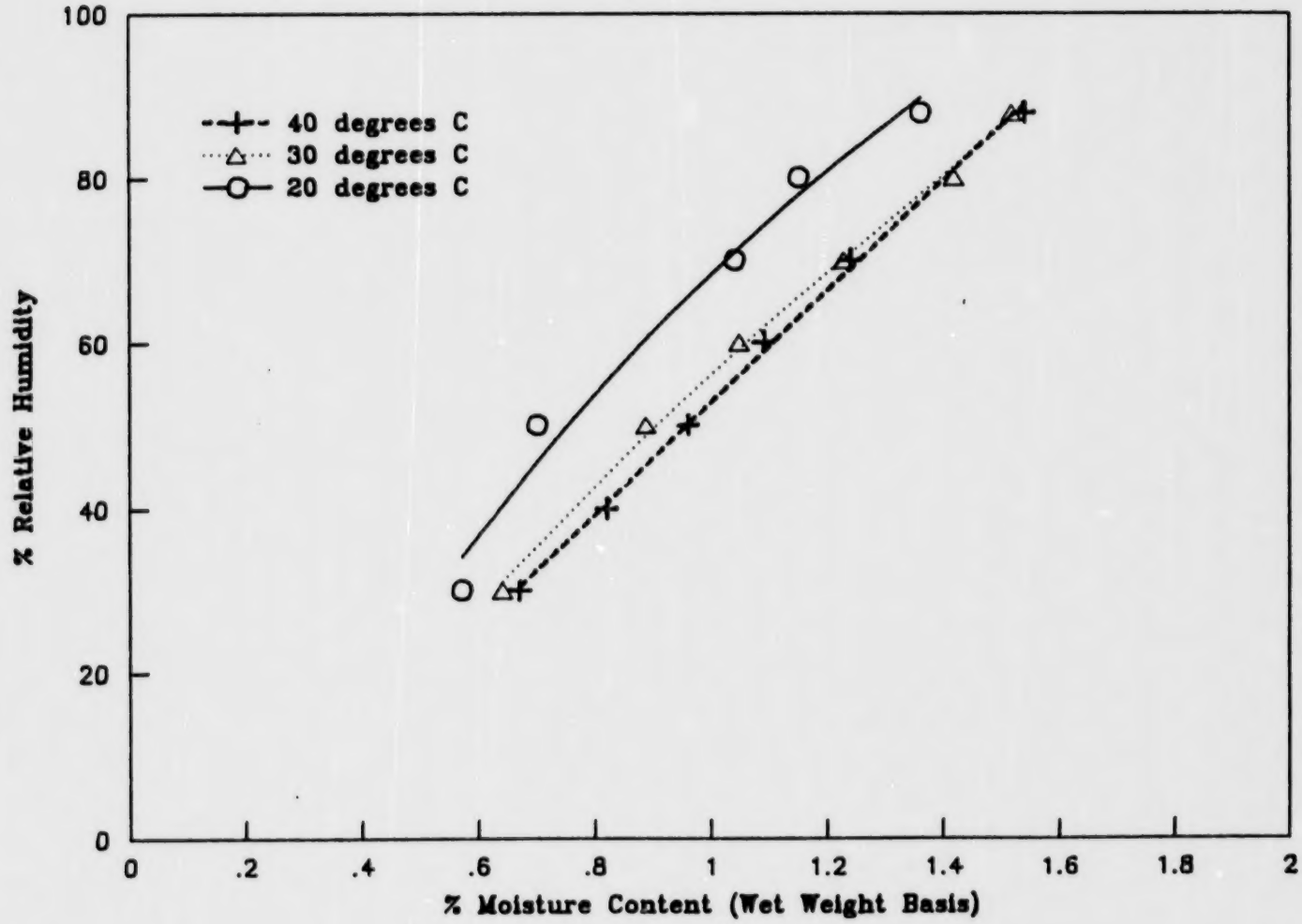


Figure 8.9
Moisture Sorption Characteristics of Test Sample Coal B_{w+5} at Different Temperatures and Relative Humidities

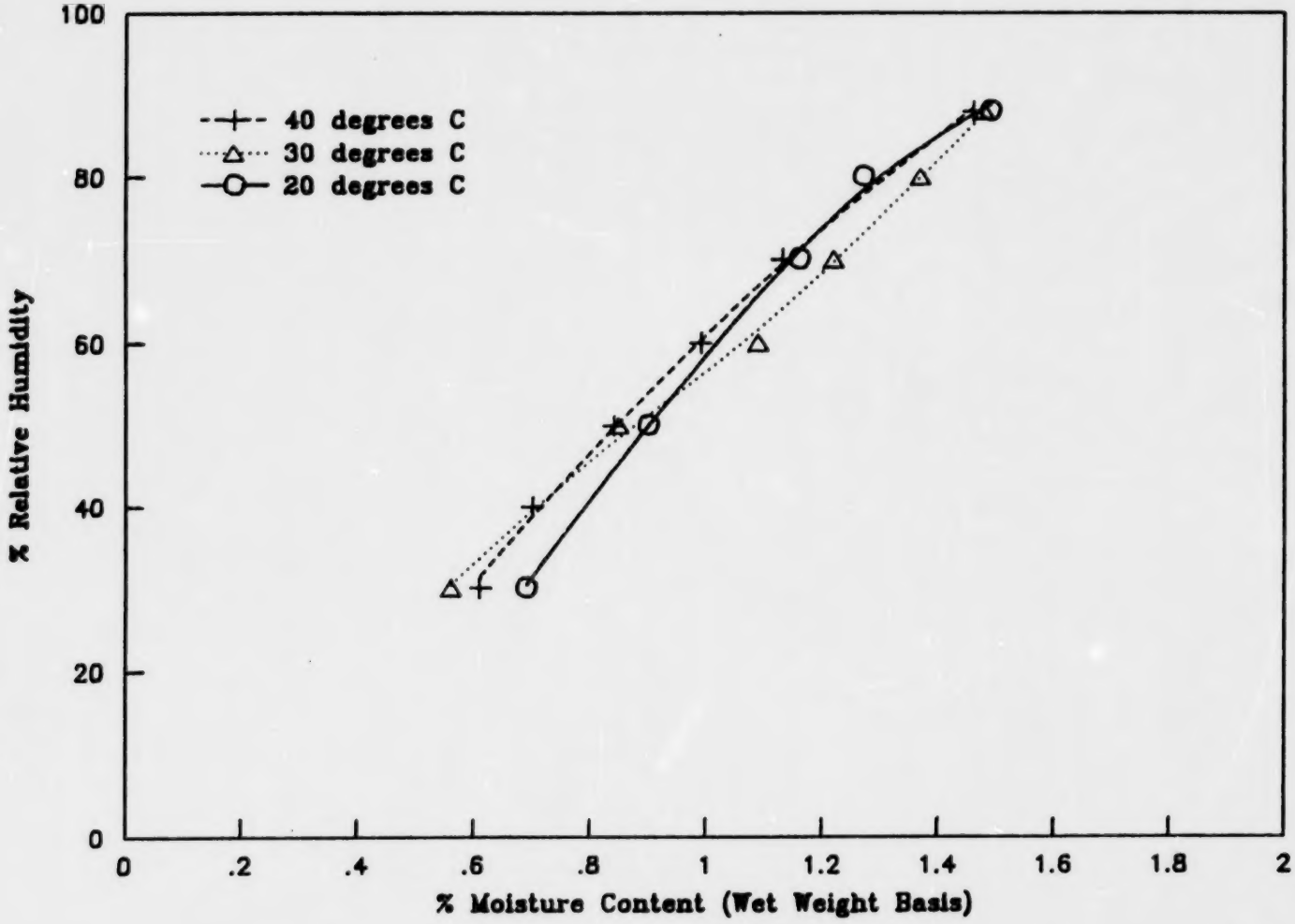


Figure 8.10
Moisture Sorption Characteristics of Test Sample Coal B_{w+2} at Different Temperatures and Relative Humidities

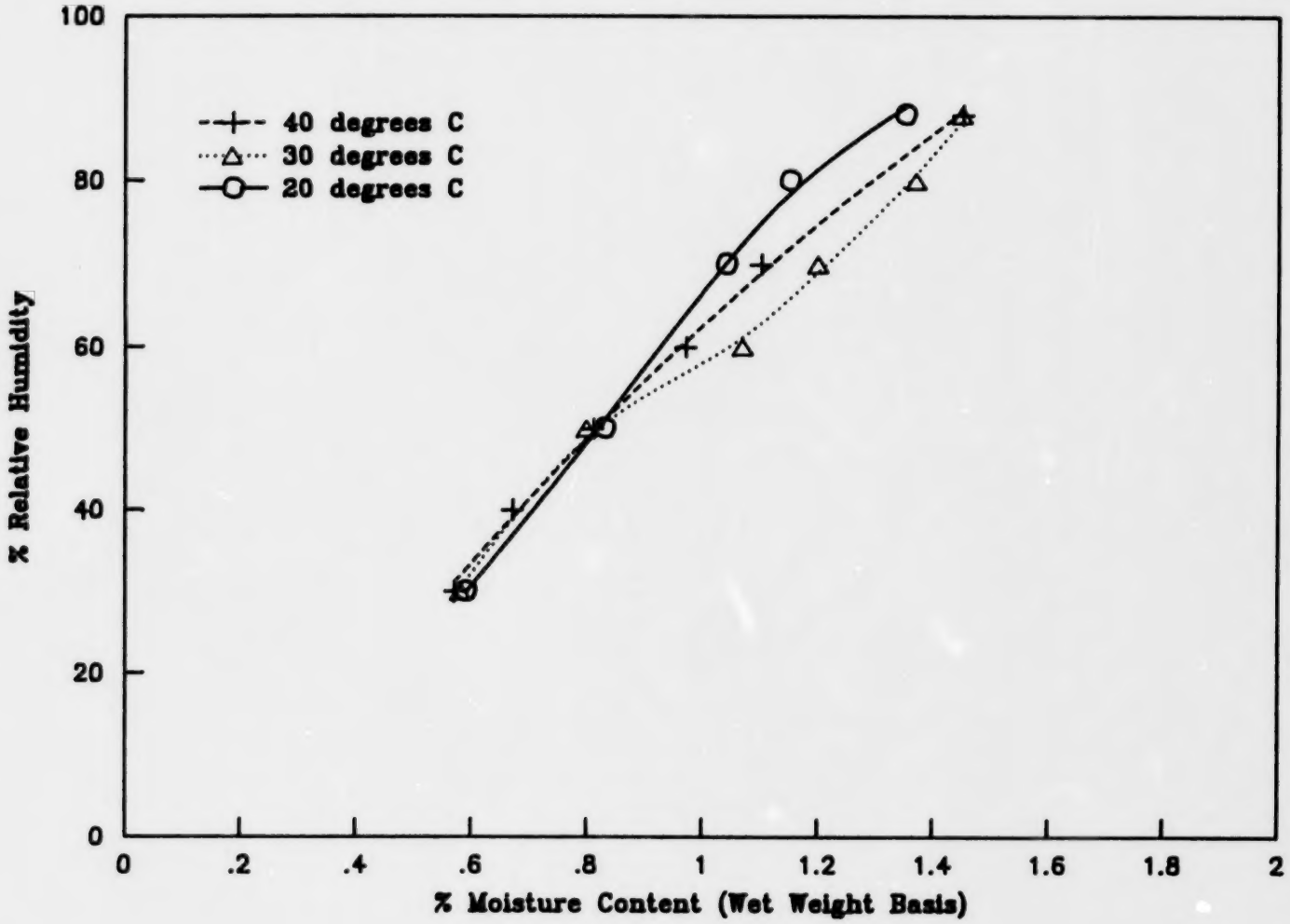


Figure 8.11
Moisture Sorption Characteristics of Test Sample Coal B_{w-1} at Different Temperatures and Relative Humidities

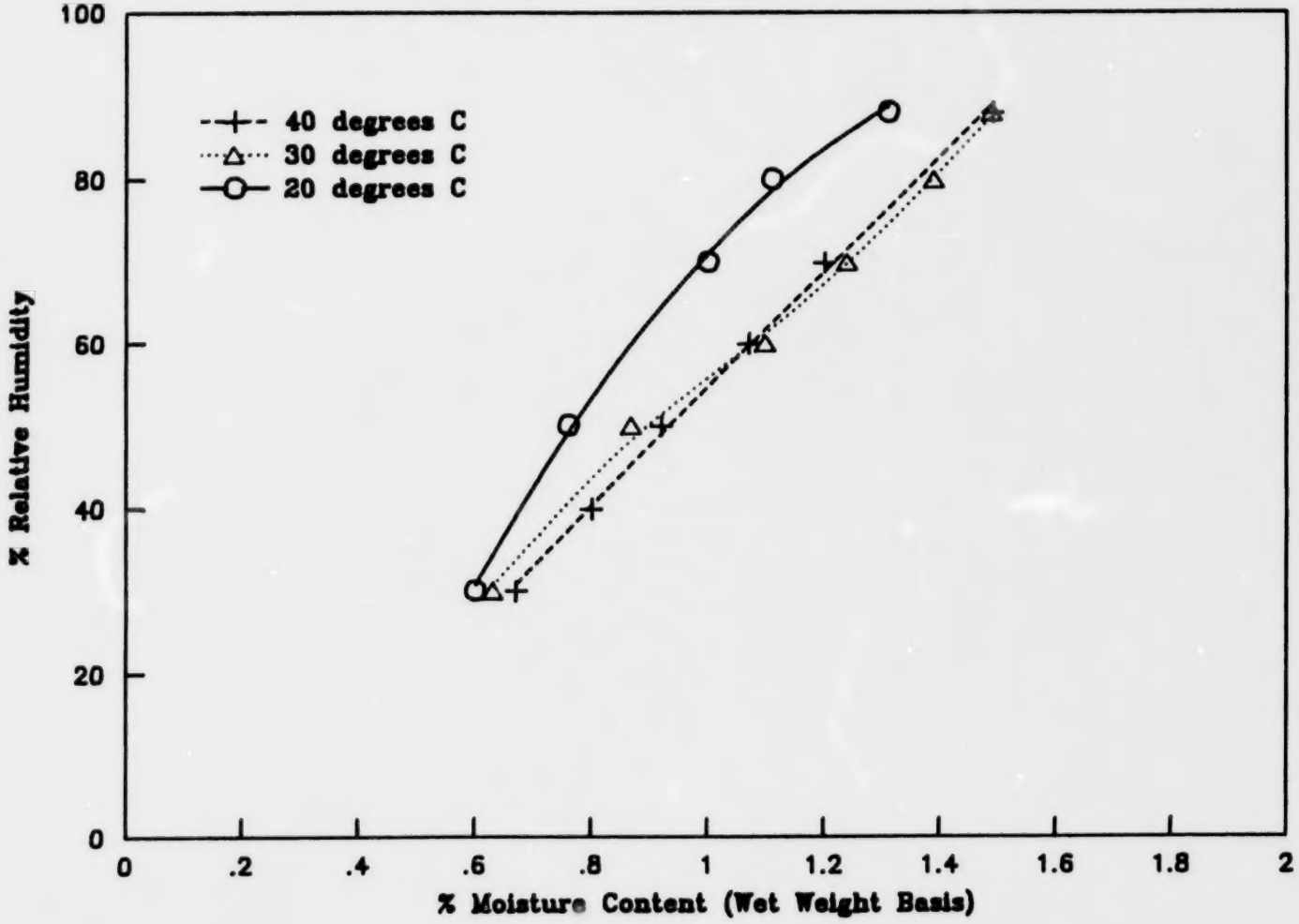


Figure 8.12
Effects of Thermal Drying on Moisture Sorption Characteristics of Medium Volatile Bituminous Coal at 20 ° C

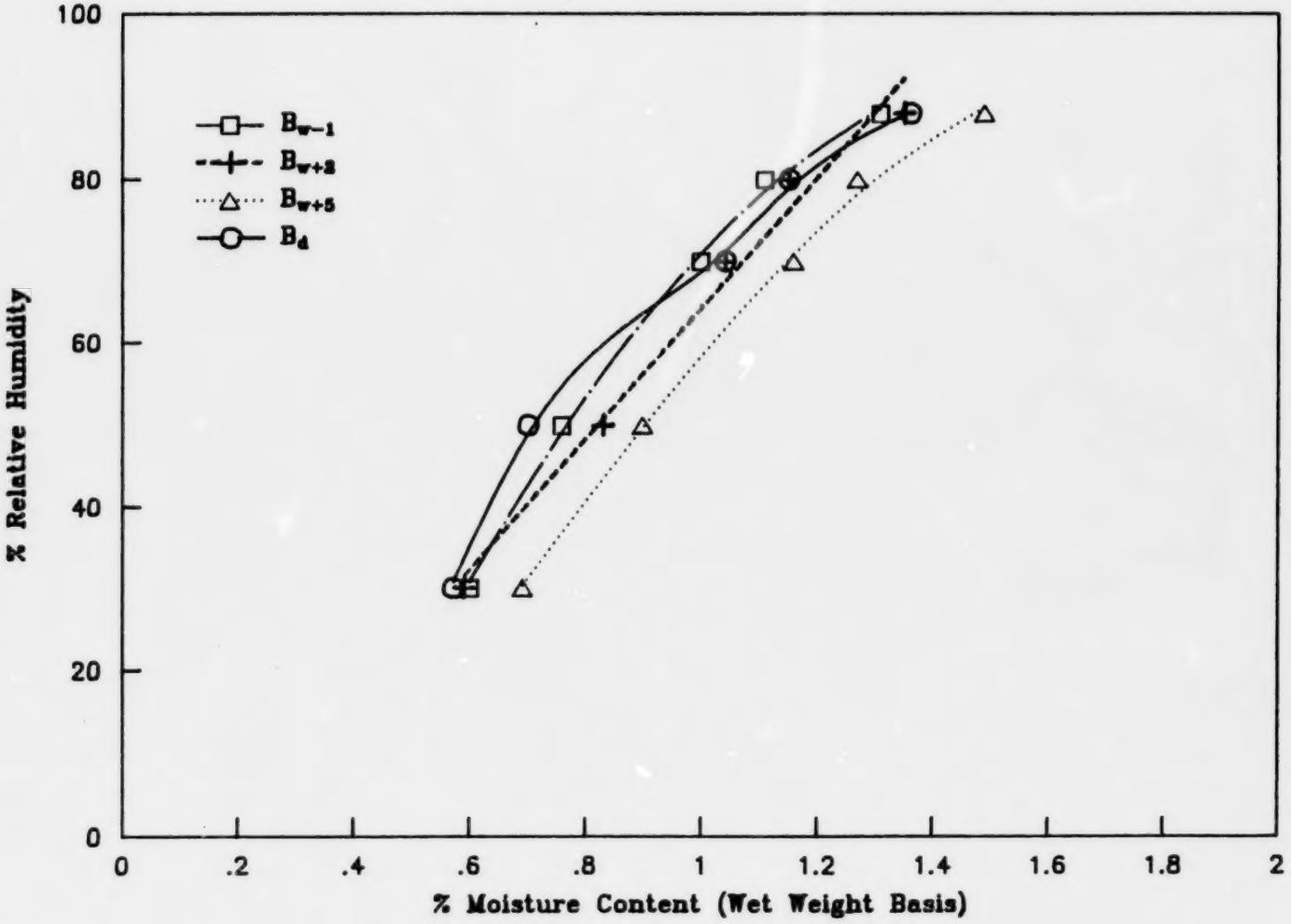


Figure 8.13
Effects of Thermal Drying on Moisture Sorption Characteristics of Medium Volatile Bituminous Coal at 30 ° C

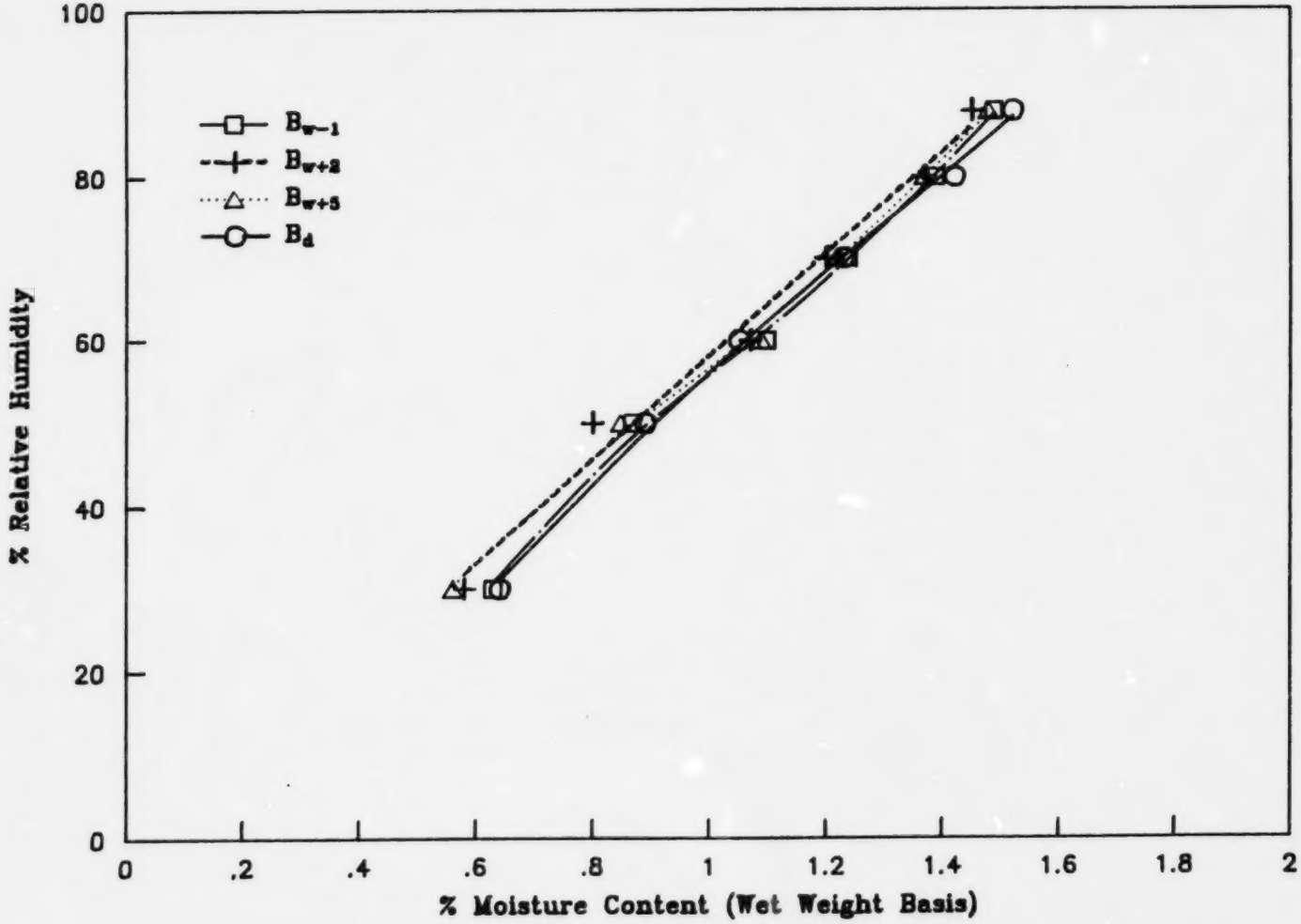
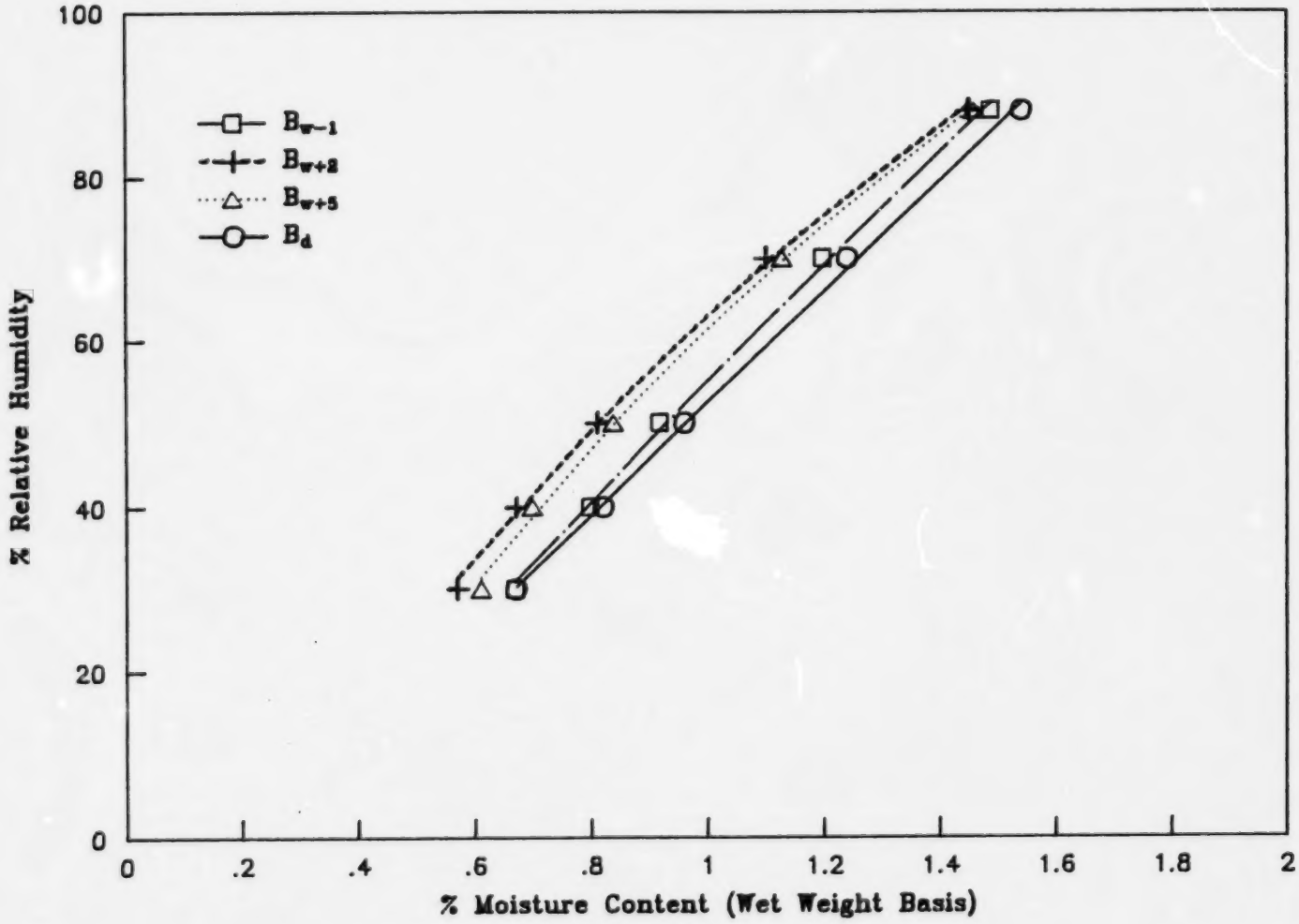


Figure 8.14
Effects of Thermal Drying on Moisture Sorption Characteristics of Medium Volatile Bituminous Coal at 40 ° C



9. DISCUSSION OF RESULTS

The term "moisture content at equilibrium with the atmosphere" used throughout this discussion is defined as the moisture holding capacity of coal at any given atmospheric temperature and relative humidity expressed as % total moisture content of the coal on a wet-weight basis.

(It should not be confused with ASTM equilibrium moisture content which is moisture holding capacity of coal crushed to pass through a 16 mesh (1.18 mm) sieve at 30°C and 96 - 97% relative humidity, also expressed as % total moisture content on wet-weight basis).

9.1 Sample Characterization

To confirm that the four samples A_w, A_d, B_w and B_d collected for the study program were of the producers' normal specifications a sub-sample of each was analysed for total moisture, ash content, calorific value, free swelling index and equilibrium moisture content. The results of these tests and the values reported by the producers are summarized in Table 4.1. The separate analyses gave comparable results.

9.2 Homogeniety of Test Samples

Equilibrium moisture (30°C & 96% R.H.) and size consist was determined using sub-samples of the eight set #1 test samples. The results are given in Tables 6.2 and 6.3 Similar size consists for the four test samples of coal A (hvcb) and for the four test samples fo coal B (mvb) confirmed the homogeniety of the test samples prepared for the study.

9.3 Moisture Sorption Characteristics

The major objectives for this present test series were to determine the effects of relative humidity, temperature and level of thermal drying on the moisture sorption characteristics of the high volatile C bituminous and medium volatile bituminous coals.

9.3.1 Effect of Relative Humidity

Figures 8.1 to 8.4 are the graphs showing the relationship between % total moisture and % relative humidity of the test samples A_d, A_{w+1}, A_{w-2}, A_{w-5} of the high volatile C bituminous thermal coal. Similarly Figures 8.8 to 8.11 are the graphs showing the relationship between % total moisture and % relative humidity of the test samples B_d, B_{w+5}, B_{w+2}, B_{w-1} of the medium volatile bituminous coal. Data was collected at 20, 30 and 40°C, each time with a new set of eight samples.

These graphs indicate that at a given temperature the equilibrium moisture content of the test samples increased with the increase of relative humidity value.

It was observed that the test samples of high volatile C bituminous coal needed more time to attain moisture sorption equilibrium at given values of temperature and relative humidity than the test samples of medium volatile bituminous coal (see Appendices 1-3 data sheets).

9.3.2 Effect of Temperature

Generally as the temperature increases for a given relative humidity the ASTM equilibrium moisture content is expected to decrease.

The graphs shown in Figures 8.1 to 8.4 and 8.8 to 8.11 are for the test samples at commercial size consists. The "moisture content in equilibrium with the atmosphere" appears to be independent of the temperature between 20°C to 40°C.

This indicates that moisture holding capacity of a commerical product cannot be predicted by the ASTM D1412 test procedure.

9.3.3 Effect of Thermal Drying

Figures 8.5 to 8.7 of the test samples of high volatile C bituminous coal and Figures 8.12 to 8.14 of the test samples of medium volatile bituminous coal and the ASTM equilibrium moisture values of the test samples of both coals given in Tables 6.2 and 6.3 indicate that either thermal drying did not change the moisture sorption characteristics of both coals or the coalification process has advanced so far that the water remaining in the pores no longer interacts with coal substance.

10. CONCLUSIONS

10.1 Thermal drying, moisture adsorption and moisture desorption were successfully studied for two commercial coals; a high volatile bituminous thermal coal and a medium volatile bituminous metallurgical coal.

10.2 Thermal drying and subsequent exposure to a wide range of atmospheric conditions did not alter the moisture holding capacity of either coal.

10.3 If these two coals are thermally dried to moisture contents less than they normally can hold in equilibrium with the atmosphere, they will return to the approximate equilibrium values on prolonged exposure to the atmospheric conditions. Hence, if the coal is exposed to a wet atmosphere some of the benefit of thermal drying is lost.

10.4 The moisture holding capacities of the commercial products of these two coals at a given relative humidity are essentially independent of temperature between 20 and 40°C.

11. RECOMMENDATIONS

Bituminous coals may be thermally dried to lower levels of moisture content than is currently commercially practiced in so far as moisture will only be readsorbed if there is prolonged exposure to wet atmospheric conditions.

However, it must be understood that this recommendation relates only to the problem of moisture re-adsorption and its implementation is dependant on the development of methods to control dustiness and spontaneous combustion. These can only be aggravated by such drying, since it does not alter such coal pore structure.

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MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_d
Weight of pan and sample = 5,000 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 7.53%
Dry Solids = 4494 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	5000		
Feb. 5	88	5007		
Feb. 10	88	5012		
Feb. 12	88	5013		
Feb. 14	88	5014		
Feb. 17	88	5015		
Feb. 19	88	5015		
Feb. 21	88	5015		
Feb. 25	next setting	5015	8.48	7.82
Feb. 27	80	5006		
Mar. 3	80	5004		
Mar. 5	80	5000		
Mar. 7	next setting	5000	8.14	7.53
Mar. 10	70	4990		
Mar. 11	70	4985		
Mar. 12	next setting	4985	7.81	7.24
Mar. 14	50	4953		
Mar. 17	50	4948		
Mar. 18	50	4945		
Mar. 29	50	4942		
Mar. 20	50	4941		
Mar. 21	next setting	4941	6.83	6.39
Mar. 24	30	4915		
Mar. 25	30	4905		
Mar. 26	30	4900		
Mar. 27	30	4900	5.92	5.59

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w+1}
Weight of pan and sample = 4932 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 10.50%
Dry Solids = 4289 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	4932		
Feb. 5	88	4870		
Feb. 10	88	4798		
Feb. 12	88	4790		
Feb. 14	88	4788		
Feb. 17	88	4786		
Feb. 19	88	4786		
Feb. 21	88	4785		
Feb. 25	next setting	4785	8.30	7.66
Feb. 27	80	4775		
Mar. 3	80	4772		
Mar. 5	80	4770		
Mar. 7	next setting	4770	7.95	7.36
Mar. 10	70	4765		
Mar. 11	70	4760		
Mar. 12	next setting	4760	7.72	7.17
Mar. 14	50	4730		
Mar. 17	50	4725		
Mar. 18	50	4720		
Mar. 29	50	4717		
Mar. 20	50	4716		
Mar. 21	next setting	4716	6.69	6.27
Mar. 24	30	4690		
Mar. 25	30	4678		
Mar. 26	30	4675		
Mar. 27	30	4675	5.74	5.43

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-2}
Weight of pan and sample = 4905 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 7.41%
Dry Solids = 4412 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	4905		
Feb. 5	88	4913		
Feb. 10	88	4920		
Feb. 12	88	4922		
Feb. 14	88	4923		
Feb. 17	88	4924		
Feb. 19	88	4925		
Feb. 21	88	4925		
Feb. 25	next setting	4925	8.45	7.79
Feb. 27	80	4915		
Mar. 3	80	4910		
Mar. 5	80	4905		
Mar. 7	next setting	4905	8.00	7.41
Mar. 10	70	4903		
Mar. 11	70	4900		
Mar. 12	next setting	4900	7.89	7.31
Mar. 14	50	4868		
Mar. 17	50	4864		
Mar. 18	50	4859		
Mar. 29	50	4857		
Mar. 20	50	4856		
Mar. 21	next setting	4856	6.89	6.45
Mar. 24	30	4828		
Mar. 25	30	4817		
Mar. 26	30	4815		
Mar. 27	30	4815	5.96	5.62

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-5}
Weight of pan and sample = 4949 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 4.88%
Dry Solids = 4574 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	4949		
Feb. 5	88	5020		
Feb. 10	88	5063		
Feb. 12	88	5073		
Feb. 14	88	5079		
Feb. 17	88	5081		
Feb. 19	88	5083		
Feb. 21	88	5085		
Feb. 25	next setting	5085	8.11	7.50
Feb. 27	80	5070		
Mar. 3	80	5065		
Mar. 5	80	5060		
Mar. 7	next setting	5060	7.56	7.03
Mar. 10	70	5044		
Mar. 11	70	5040		
Mar. 12	next setting	5040	7.13	6.66
Mar. 14	50	5035		
Mar. 17	50	5030		
Mar. 18	50	5024		
Mar. 29	50	5022		
Mar. 20	50	5022		
Mar. 21	next setting	5022	6.73	6.31
Mar. 24	30	4998		
Mar. 25	30	4989		
Mar. 26	30	4985		
Mar. 27	30	4985	5.92	5.59

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_d
Weight of pan and sample = 5005 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 6.13 %
Dry Solids = 4567 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	5005		
Feb. 5	88	4901		
Feb. 10	88	4830		
Feb. 12	88	4810		
Feb. 14	88	4795		
Feb. 17	88	4775		
Feb. 19	88	4772		
Feb. 21	88	4770		
Feb. 25	next setting	4770	1.38	1.36
Feb. 27	80	4765		
Mar. 3	80	4762		
Mar. 5	80	4760		
Mar. 7	next setting	4760	1.16	1.15
Mar. 10	70	4756		
Mar. 11	70	4755		
Mar. 12	next setting	4755	1.05	1.04
Mar. 14	50	4739		
Mar. 17	50	4739		
Mar. 18	50	4739		
Mar. 29	50	4739		
Mar. 20	50	4739		
Mar. 21	next setting	4739	0.70	0.70
Mar. 24	30	4734		
Mar. 25	30	4733		
Mar. 26	30	4733		
Mar. 27	30	4733	0.57	0.57

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+5}
Weight of pan and sample = 5005 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 7.26%
Dry Solids = 4512 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	5005		
Feb. 5	88	4870		
Feb. 10	88	4780		
Feb. 12	88	4750		
Feb. 14	88	4730		
Feb. 17	88	4724		
Feb. 19	88	4722		
Feb. 21	88	4720		
Feb. 25	next setting	4720	1.51	1.49
Feb. 27	80	4715		
Mar. 3	80	4713		
Mar. 5	80	4710		
Mar. 7	next setting	4710	1.29	1.27
Mar. 10	70	4708		
Mar. 11	70	4705		
Mar. 12	next setting	4705	1.17	1.16
Mar. 14	50	4698		
Mar. 17	50	4696		
Mar. 18	50	4695		
Mar. 29	50	4693		
Mar. 20	50	4693		
Mar. 21	next setting	4693	0.91	0.90
Mar. 24	30	4868		
Mar. 25	30	4683		
Mar. 26	30	4683		
Mar. 27	30	4683	0.69	0.69

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+2}
Weight of pan and sample = 5005 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 2.56%
Dry Solids = 4740 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	5005		
Feb. 5	88	4977		
Feb. 10	88	4955		
Feb. 12	88	4950		
Feb. 14	88	4948		
Feb. 17	88	4946		
Feb. 19	88	4945		
Feb. 21	88	4945		
Feb. 25	next setting	4945	1.37	1.35
Feb. 27	80	4940		
Mar. 3	80	4938		
Mar. 5	80	4935		
Mar. 7	next setting	4935		
Mar. 10	70	4931		
Mar. 11	70	4930		
Mar. 12	next setting	4930	1.05	1.04
Mar. 14	50	4925		
Mar. 17	50	4923		
Mar. 18	50	4920		
Mar. 29	50	4920		
Mar. 20	50	4920		
Mar. 21	next setting	4920	0.84	0.83
Mar. 24	30	4912		
Mar. 25	30	4908		
Mar. 26	30	4908		
Mar. 27	30	4908	0.59	0.59

MOISTURE SORPTION AT 20°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w-1}
Weight of pan and sample = 5000 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 0.59%
Dry Solids = 4831 gms

Task: 8579

1986	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
Feb. 3	88	5000		
Feb. 5	88	5016		
Feb. 10	88	5030		
Feb. 12	88	5033		
Feb. 14	88	5035		
Feb. 17	88	5035		
Feb. 19	88	5035		
Feb. 21	88	5035		
Feb. 25	next setting	5035	1.32	1.30
Feb. 27	80	5030		
Mar. 3	80	5027		
Mar. 5	80	5025		
Mar. 7	next setting	5025	1.12	1.11
Mar. 10	70	5020		
Mar. 11	70	5020		
Mar. 12	next setting	5020	1.01	1.00
Mar. 14	50	5014		
Mar. 17	50	5013		
Mar. 18	50	5008		
Mar. 29	50	5008		
Mar. 20	50	5008		
Mar. 21	next setting	5008	0.77	0.76
Mar. 24	30	5002		
Mar. 25	30	5000		
Mar. 26	30	5000		
Mar. 27	30	5000	0.60	0.60

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_d
Weight of pan and sample = 4159 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 7.31%
Dry Solids = 3725 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4159		
Apr. 1	88	4170*		
Apr. 9	88	4165		
Apr. 10	88	4172		
Apr. 11	88	4177		
Apr. 14	88	4181		
Apr. 15	88	4812		
Apr. 16	88	4813		
Apr. 17	88	4183		
Apr. 18	88	4184		
Apr. 21	next setting	4184	8.56	7.89
Apr. 22	80	4179		
Apr. 23	80	4179		
Apr. 24	80	4178		
Apr. 25	80	4177		
Apr. 28	80	4176		
Apr. 29	next setting	4176	8.35	7.71
Apr. 30	70	4169		
May 1	70	4164		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_d
Weight of pan and sample = 4159 gms.
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 7.31%
Dry Solids = 3725 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1985				
May 2	70%	4163		
May 5	next setting	4161	7.95	7.36
May 6	60%	4154		
May 7	60%	4149		
May 9	60%	4142		
May 12	next setting	4142	7.44	6.92
May 13	50%	4135		
May 14	50%	4129		
May 15	50%	4127		
May 16	50%	4122		
May 20	next setting	4120	6.85	6.41
May 21	30%	4106		
May 22	30%	4089		
May 23	30%	4075		
May 26	30%	4067		
May 27	30%	4060		
May 28	30%	4060	5.23	4.97

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w+1}
Weight of pan and sample = 4140 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 10.15%
Dry Solids = 3594 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4140		
Apr. 1	88	4048*		
Apr. 9	88	4034		
Apr. 10	88	4038		
Apr. 11	88	4040		
Apr. 14	88	4043		
Apr. 15	88	4043		
Apr. 16	88	4044		
Apr. 17	88	4044		
Apr. 18	88	4045		
Apr. 21	next setting	4045	8.65	7.96
Apr. 22	80	4043		
Apr. 23	80	4040		
Apr. 24	80	4037		
Apr. 25	80	4037		
Apr. 28	80	4037		
Apr. 29	next setting	4037	8.43	7.77
Apr. 30	70	4030		
May 1	70	4026		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w+1}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 10.15%
Dry Solids = 3594 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	4025		
May 5	next setting	4023	8.04	7.44
May 6	60%	4017		
May 7	60%	4011		
May 9	60%	4005		
May 12	next setting	4005	7.54	7.01
May 13	50%	3997		
May 14	50%	3992		
May 15	50%	3989		
May 16	50%	3986		
May 20	next setting	3984	6.96	6.51
May 21	30%	3968		
May 22	30%	3952		
May 23	30%	3939		
May 26	30%	3929		
May 27	30%	3924		
May 28	30%	3924	5.29	5.02

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-2}
Weight of pan and sample = 4140 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 8.76 %
Dry Solids = 3650 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4140		
Apr. 1	88	4099*		
Apr. 9	88	4086		
Apr. 10	88	4091		
Apr. 11	88	4095		
Apr. 14	88	4098		
Apr. 15	88	4099		
Apr. 16	88	4101		
Apr. 17	88	4101		
Apr. 18	88	4102		
Apr. 21	next setting	4102	8.55	7.88
Apr. 22	80	4097		
Apr. 23	80	4095		
Apr. 24	80	4094		
Apr. 25	80	4093		
Apr. 28	80	4093		
Apr. 29	next setting	4093	8.30	7.66
Apr. 30	70	4085		
May 1	70	4081		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-2}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 8.76%
Dry Solids = 3650 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	4079		
May 5	next setting	4079	7.92	7.34
May 6	60%	4072		
May 7	60%	4067		
May 9	60%	4059		
May 12	next setting	4059	7.42	6.91
May 13	50%	4052		
May 14	50%	4047		
May 15	50%	4044		
May 16	50%	4039		
May 20	next setting	4039	6.82	6.38
May 21	30%	4021		
May 22	30%	4005		
May 23	30%	3993		
May 26	30%	3984		
May 27	30%	3980		
May 28	30%	3980	5.21	4.95

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-5}
Weight of pan and sample = 4144 gms
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 5.81%
Dry Solids = 3771 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4144		
Apr. 1	88	4200*		
Apr. 9	88	4202		
Apr. 10	88	4210		
Apr. 11	88	4215		
Apr. 14	88	4222		
Apr. 15	88	4224		
Apr. 16	88	4224		
Apr. 17	88	4225		
Apr. 18	88	4227		
Apr. 21	next setting	4227	8.38	7.73
Apr. 22	80	4224		
Apr. 23	80	4221		
Apr. 24	80	4220		
Apr. 25	80	4220		
Apr. 28	80	4220		
Apr. 29	next setting	4220	8.19	7.57
Apr. 30	70	4212		
May 1	70	4208		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-5}
Weight of pan and sample = 4144 gms.
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 5.81%
Dry Solids = 3771 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	4207		
May 5	next setting	4207	7.85	7.28
May 6	60%	4199		
May 7	60%	4194		
May 9	60%	4190		
May 12	next setting	4190	7.40	6.89
May 13	50%	4182		
May 14	50%	4177		
May 15	50%	4174		
May 16	50%	4169		
May 20	next setting	4169	6.84	6.40
May 21	30%	4154		
May 22	30%	4139		
May 23	30%	4127		
May 26	30%	4117		
May 27	30%	4112		
May 28	30%	4112	5.33	5.06

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_d
Weight of pan and sample = 4149 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 6.20%
Dry Solids = 3760 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4149		
Apr. 1	88	3976*		
Apr. 9	88	3952		
Apr. 10	88	3955		
Apr. 11	88	3956		
Apr. 14	88	3957		
Apr. 15	88	3958		
Apr. 16	88	3958		
Apr. 17	88	3958		
Apr. 18	88	3958		
Apr. 21	next setting	3958	1.54	1.52
Apr. 22	80	3954		
Apr. 23	80	3954		
Apr. 24	80	3954		
Apr. 25	80	3954		
Apr. 28	80	3954		
Apr. 29	next setting	3954	1.44	1.42
Apr. 30	70	3950		
May 1	70	3947		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_d
Weight of pan and sample = 4149 gms.
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 6.20%
Dry Solids = 3760 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	3947		
May 5	next setting	3947	1.25	1.23
May 6	60%	3943		
May 7	60%	3940		
May 9	60%	3940		
May 12	next setting	3940	1.06	1.05
May 13	50%	3938		
May 14	50%	3936		
May 15	50%	3935		
May 16	50%	3934		
May 20	next setting	3934	0.90	0.89
May 21	30%	3928		
May 22	30%	2926		
May 23	30%	3925		
May 26	30%	3924		
May 27	30%	3924		
May 28	30%	3924	0.64	0.64

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+5}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 6.66%
Dry Solids = 3734 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4140		
Apr. 1	88	3971*		
Apr. 9	88	3923		
Apr. 10	88	3926		
Apr. 11	88	3927		
Apr. 14	88	3929		
Apr. 15	88	3929		
Apr. 16	88	3929		
Apr. 17	88	3929		
Apr. 18	88	3930		
Apr. 21	next setting	3930	1.50	1.48
Apr. 22	80	3927		
Apr. 23	80	3926		
Apr. 24	80	3926		
Apr. 25	80	3926		
Apr. 28	80	3926		
Apr. 29	next setting	3926	1.39	1.37
Apr. 30	70	3922		
May 1	70	3920		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+5}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 6.66%
Dry Solids = 3724 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	3920		
May 5	next setting	3920	1.23	1.22
May 6	60%	3916		
May 7	60%	3915		
May 9	60%	3915		
May 12	next setting	3915	1.10	1.09
May 13	50%	3911		
May 14	50%	3910		
May 15	50%	3908		
May 16	50%	3906		
May 20	next setting	3906	0.86	0.85
May 21	30%	3902		
May 22	30%	3898		
May 23	30%	3896		
May 26	30%	3895		
May 27	30%	3895		
May 28	30%	3985	0.56	0.56

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+2}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms
Moisture Content (M_{ar}) = 4.88%
Dry Solids = 3805 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4140		
Apr. 1	88	4032*		
Apr. 9	88	3996		
Apr. 10	88	3999		
Apr. 11	88	4000		
Apr. 14	88	4000		
Apr. 15	88	4000		
Apr. 16	88	4000		
Apr. 17	88	4001		
Apr. 18	88	4001		
Apr. 21	next setting	4001	1.47	1.45
Apr. 22	80	3999		
Apr. 23	80	3998		
Apr. 24	80	3998		
Apr. 25	80	3998		
Apr. 28	80	3998		
Apr. 29	next setting	3998	1.39	1.37
Apr. 30	70	3993		
May 1	70	3991		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+2}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 4.88%
Dry Solids = 3805 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	3991		
May 5	next setting	3991	1.21	1.20
May 6	60%	3987		
May 7	60%	3986		
May 9	60%	3986		
May 12	next setting	3986	1.08	1.07
May 13	50%	3982		
May 14	50%	3980		
May 15	50%	3978		
May 16	50%	3976		
May 20	next setting	3976	0.81	0.80
[illegible]y 21	30%	3972		
May 22	30%	3970		
May 23	30%	3968		
May 26	30%	3967		
May 27	30%	3967		
May 28	30%	3967	0.58	0.58

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w-1}
Weight of pan and sample = 4149 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 0.91%
Dry Solids = 3964 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
Mar. 27	88	4140		
Apr. 1	88	4158*		
Apr. 9	88	4156		
Apr. 10	88	4160		
Apr. 11	88	4161		
Apr. 14	88	4162		
Apr. 15	88	4162		
Apr. 16	88	4162		
Apr. 17	88	4163		
Apr. 18	88	4164		
Apr. 21	next setting	4164	1.51	1.49
Apr. 22	80	4162		
Apr. 23	80	4160		
Apr. 24	80	4160		
Apr. 25	80	4160		
Apr. 28	80	4160		
Apr. 29	next setting	4160	1.41	1.39
Apr. 30	70	4156		
May 1	70	4155		

* Test restarted after repair of environmental chamber

MOISTURE SORPTION AT 30°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w-1}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 0.91%
Dry Solids = 3964 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 2	70%	4154		
May 5	next setting	4154	1.26	1.24
May 6	60%	4150		
May 7	60%	4149		
May 9	60%	4148		
May 12	next setting	4148	1.11	1.10
May 13	50%	4144		
May 14	50%	4142		
May 15	50%	4140		
May 16	50%	4139		
May 20	next setting	4139	0.88	0.87
May 21	30%	4136		
May 22	30%	4132		
May 23	30%	4130		
May 26	30%	4129		
May 27	30%	4129		
May 28	30%	4129	0.63	0.63

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_d
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 7.39%
Dry Solids = 3704gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	4140		
June 4	88	4140		
June 6	88	4141	8.02	7.42
	Next setting 70% RH			
June 9	70	4117		
June 10	70	4115		
June 11	70	4113		
June 12	70	4113	7.26	6.77
	Next setting 60% RH			
June 13	60	4101		
June 16	60	4095		
June 17	60	4094	6.75	6.32
	Next setting 50% RH			
June 18	50	4082		
June 19	50	4076		
June 20	50	4076		
June 23	50	4067		
June 24	50	4067	6.02	5.68
	Next setting 40% RH			
June 25	40	4053		
June 26	40	4046		
June 27	40	4042		
July 2	40	4038		
July 3	40	4038	5.24	4.97
	Next setting 30% RH			
July 4	30	4027		
July 7	30	4020		
July 8	30	4020	4.75	4.53

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w+1}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 8.80%
Dry Solids = 3648 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	4096		
June 4	88	4095		
June 6	88	4095	8.42	7.77
	Next setting 70% RH			
June 9	70	4068		
June 10	70	4066		
June 11	70	4064		
June 12	70	4064	7.57	7.04
	Next setting 60% RH			
June 13	60	4053		
June 16	60	4046		
June 17	60	4045	7.04	6.58
	Next setting 50% RH			
June 18	50	4043		
June 19	50	4027		
June 20	50	4023		
June 23	50	4017		
June 24	50	4017	6.28	5.91
	Next setting 40% RH			
June 25	40	4004		
June 26	40	4997		
June 27	40	3993		
July 2	40	3998		
July 3	40	3987	5.46	5.18
	Next setting 30% RH			
July 4	30	3978		
July 7	30	3970		
July 8	30	3969	4.96	4.73

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-2}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 6.33%
Dry Solids = 3747 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	4184		
June 4	88	4189		
June 6	88	4191	8.11	7.50
	Next setting 70% RH			
June 9	70	4167		
June 10	70	4166		
June 11	70	4165		
June 12	70	4165	7.42	6.91
	Next setting 60% RH			
June 13	60	4154		
June 16	60	4148		
June 17	60	4148	6.96	6.52
	Next setting 50% RH			
June 18	50	4136		
June 19	50	4130		
June 20	50	4126		
June 23	50	4122		
June 24	50	4122	6.27	5.90
	Next setting 40% RH			
June 25	40	4108		
June 26	40	4101		
June 27	40	4097		
July 2	40	4092		
July 3	40	4091	5.44	5.16
	Next setting 30% RH			
July 4	30	4080		
July 7	30	4076		
July 8	30	4076	5.04	4.80

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: A_{w-5}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 5.14%
Dry Solids = 3794 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88			
June 2	88	4140		
June 4	88	4239		
June 6	88	4250	8.43	7.77
	Next setting 70% RH			
June 9	70	4230		
June 10	70	4229		
June 11	70	4227		
June 12	70	4227	7.72	7.17
	Next setting 60% RH			
June 13	60	4218		
June 16	60	4212		
June 17	60	4212	7.33	6.83
	Next setting 50% RH			
June 18	50	4201		
June 19	50	4195		
June 20	50	4191		
June 23	50	4186		
June 24	50	4186	6.64	6.23
	Next setting 40% RH			
June 25	40	4174		
June 26	40	4167		
June 27	40	4162		
July 2	40	4149		
July 3	40	4142	5.64	5.33
	Next setting 30% RH			
July 4	30	4135		
July 7	30	4131		
July 8	30	4130	5.17	4.92

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_d
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 6.85%
Dry Solids = 3726 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	3949		
June 4	88	3925		
June 6	88	3924	1.56	1.54
	Next setting 70% RH			
June 9	70	3913		
June 10	70	3913		
June 11	70	3913		
June 12	70	3913	1.26	1.24
	Next setting 60% RH			
June 13	60	3907		
June 16	60	3907		
June 17	60	3907	1.10	1.09
	Next setting 50% RH			
June 18	50	3903		
June 19	50	3903		
June 20	50	3902		
June 23	50	3902		
June 24	50	3902	0.97	0.96
	Next setting 40% RH			
June 25	40	2897		
June 26	40	3897		
June 27	40	3897		
July 2	40	3897		
July 3	40	3897	0.83	0.82
	Next setting 30% RH			
July 4	30	3893		
July 7	30	3891		
July 8	30	3891	0.67	0.67

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+5}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 5.34%
Dry Solids = 3786 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	4031		
June 4	88	3988		
June 6	88	3982	1.48	1.46
	Next setting 70% RH			
June 9	70	3970		
June 10	70	3969		
June 11	70	3969		
June 12	70	3969	1.14	1.13
	Next setting 60% RH			
June 13	60	3964		
June 16	60	3964		
June 17	60	3964	1.00	0.99
	Next setting 50% RH			
June 18	50	3959		
June 19	50	3958		
June 20	50	3958		
June 23	50	3958		
June 24	50	3958	0.85	0.84
	Next setting 40% RH			
June 25	40	3953		
June 26	40	3953		
June 27	40	3953		
July 2	40	3953		
July 3	40	3953	0.71	0.70
	Next setting 30% RH			
July 4	30	3951		
July 7	30	3949		
July 8	30	3949	0.61	0.61

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w+2}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 2.38%
Dry Solids = 3887 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	4089		
June 4	88	4085		
June 6	88	4084	1.47	1.45
	Next setting 70% RH			
June 9	70	4071		
June 10	70	4070		
June 11	70	4070		
June 12	70	4070	1.11	1.10
	Next setting 60% RH			
June 13	60	4065		
June 16	60	4065		
June 17	60	4065	0.98	0.97
	Next setting 50% RH			
June 18	50	4060		
June 19	50	4059		
June 20	50	4059		
June 23	50	4059		
June 24	50	4059	0.82	0.81
	Next setting 40% RH			
June 25	40	4054		
June 26	40	4053		
June 27	40	4053		
July 2	40	4053		
July 3	40	4053	0.67	0.67
	Next setting 30% RH			
July 4	30	4051		
July 7	30	4049		
July 8	30	4049	0.57	0.57

MOISTURE SORPTION AT 40°C AND DIFFERENT RELATIVE HUMIDITIES
EXPERIMENTAL DATA

Sample: B_{w-1}
Weight of pan and sample = 4140 gms.
Weight of pan = 140 gms.
Moisture Content (M_{ar}) = 0.65%
Dry Solids = 3974 gms.

Task: 8579

Date Sample weighed	% Relative Humidity	Weight of pan & sample in gms	% Moisture M_d	% Moisture M_{ad}
1986				
May 29	88	4140		
June 2	88	4171		
June 4	88	4173		
June 6	88	4174	1.51	1.49
	Next setting 70% RH			
June 9	70	4162		
June 10	70	4162		
June 11	70	4162		
June 12	70	4162	1.21	1.20
	Next setting 60% RH			
June 13	60	4157		
June 16	60	4157		
June 17	60	4157	1.08	1.07
	Next setting 50% RH			
June 18	50	4152		
June 19	50	4152		
June 20	50	4151		
June 23	50	4151		
June 24	50	4151	0.93	0.92
	Next setting 40% RH			
June 25	40	4147		
June 26	40	4146		
June 27	40	4146		
July 2	40	4146		
July 3	40	4146	0.81	0.80
	Next setting 30% RH			
July 4	30	4144		
July 7	30	4143		
July 8	30	4143	0.73	0.72

AMERICAN NATIONAL STANDARD ANSI/ASTM D 1412 - 74 (Reapproved 1979)

Standard Test Method for EQUILIBRIUM MOISTURE OF COAL AT 96 TO 97 PERCENT RELATIVE HUMIDITY AND 30°C[1]

This standard is issued under the fixed designation D 1412; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This method[2] covers determination of the equilibrium moisture of coal in an atmosphere over a saturated solution of potassium sulfate at 30°C. It affords a means of estimating the bed moisture of either coal that is wet and shows visible surface moisture, or coal that may have lost some moisture. It may be used for estimating the surface, or extraneous, moisture of wet coal, such moisture being the difference between total moisture as determined by Method D 3302 and equilibrium moisture.

1.2 When samples are collected in conformity with Classification D 388, the equilibrium moisture is considered to be equal to the bed moisture.

2. Applicable Documents

2.1 *ASTM Standards*:

D 388 Classification of Coals by Rank[3]

D 2234 Collection of a Gross Sample of Coal[3]

D 3173 Test for Moisture in the Analysis Sample of Coal and Coke[3]

D 3302 Test for Total Moisture in Coal[3]

3. Apparatus

3.1 *Water Bath or Insulated Air Cabinet*—The bath or cabinet shall be of sufficient size to accommodate several vacuum-type desiccators, and shall be provided with a temperature regulator to maintain a uniform temperature of 30.0 ± 0.2°C.

3.2 *Moisture Oven*—The oven shall be so constructed as to have a uniform temperature in all parts and a minimum of air space. It may be of the type shown in 5.1.1 of Method D 3173. Provision shall be made for renewing the air (or, if desired, dry oxygen-free nitrogen for subbituminous and lignitic coals) in the oven at the rate of two times per minute, with the air dried by passing it through H_2SO_4 (sp gr 1.84).

3.3 *Mechanical Vacuum Pump*.

3.4 *Crusher*, laboratory, coffee-mill type.

3.5 *Sieve*, 8-in. (203-mm) diameter, with 1.18-mm (No. 16) openings.

3.6 *Shaking Machine*.

3.7 *Desiccator*—Small vacuum-type desiccator, 160 mm in diameter.

3.8 *Weighing Bottles*, glass, low-form, flat-bottom, cylindrical, 70 mm in diameter, with well-fitting covers.

3.9 *Filter Pump*, aspirator.

3.10 *Buchner-Type Funnel*, approximately 2 1/2 in. (64 mm) in diameter.

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[1] This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke.

Current edition approved Feb. 27, 1974. Published April 1974. Originally published as D 1412 - 56 T. Last previous edition D 1412 - 61 (1968).

[2] For information concerning the experimental work on which this method is based, see the following papers:

Stansfield, Edgar, and Gilbart, K. C., "Moisture Determination for Coal Classification," *Transactions*, American Inst. of Mining and Metallurgical Engineers, Coal Division, TAMCA, Vol 101, 1932, pp. 125–43.

Rees, O. W., Reed, F. H., and Land, G. W., "A Study of the Equilibration Method of Determining Moisture in Coal for Classification by Rank," *Report of Investigations* No. 59, Illinois State Geological Survey, ILGA, 1939, pp. 14.

Kreulen, D. J. W., "The Adsorption Water of Coal," *Chemische en Pharmaceutische Technick* (Dordrecht), CHPHA, Vol 7, 1951, pp. 23–4.

Selvig, W. A., and Ode, W. H., "Determination of Moisture Holding Capacity (Bed Moisture) of Coal for Classification by Rank," *Report of Investigations* No. 4968, U. S. Bureau of Mines, XMBIA, 1953.

[3] *Annual Book of ASTM Standards*, Part 26.

4. Collection of Gross Samples

4.1 Samples shall not be taken from outcrop, weathered, or oxidized coal.

4.1.1 *Mine Samples*—Take the mine samples in accordance with the Bureau of Mines method,[4] and place in moisture-tight containers in the mine.

4.1.2 *Tipple or Shipment Samples*—Collect a representative gross sample of coal and prepare in accordance with Methods D 2234. If only the equilibrium moisture is desired, use the commercial sampling procedure. If the surface moisture of wet coal is to be determined, use the procedure for special moisture.

5. Preparation of Laboratory Samples

5.1 Rapidly stage-crush the samples to pass a 1.18-mm (No. 16) sieve by means of a coffee-mill type crusher. The stage crushing produces a minimum amount of fine material; however, it increases segregation so the crushed sample shall be thoroughly mixed. Spread coals that are too wet to crush in a thin layer and expose to the air of the laboratory until partly dry. Take care that low-rank coals are not overdried.

6. Procedure

6.1 Place 20 to 25 g of the crushed coal into a 250-ml Erlenmeyer flask and add 100 ml of recently boiled, cooled, distilled water (Note 1). Shake the flask mechanically for 30 min, and then place it in the constant-temperature bath for 3 h at 30°C. At the end of the wetting period, remove the excess water from the coal by filtering on a Büchner-type funnel approximately 2½ in. (64 mm) in diameter, using suction supplied by a water filter pump. Use a minimum amount of water to transfer the coal to the filter. After transfer of the coal, close the funnel with a rubber stopper fitted with a glass tube through which air saturated with water vapor is passed to prevent drying of the coal. Thoroughly mix the wet coal in the funnel with a spoon and place about 5.0 g in a uniform layer in a weighing bottle of known weight. Place the uncovered weighing bottle in the small vacuum-type desiccator containing a saturated solution of K_2SO_4 for maintaining the relative humidity of 96 to 97 percent. An excess of crystalline K_2SO_4 shall extend above the solution level. Evacuate the desiccator to an absolute pressure equivalent to about 30 mm Hg by means of a mechanical vacuum pump, and then totally immerse in a constant-temperature water bath or place in an insulated air cabinet, maintained at 30 ± 0.2°C for 48 h for all coals higher in rank than lignite. Lignite will require 72 h to reach equilibrium for practical purposes.

NOTE 1—Mine samples and certain coals that deteriorate when treated with water may be equilibrated directly without wetting, provided the samples are collected and prepared with a minimum loss of moisture. Unwetted coals should be equilibrated for varying periods of time, in units of 24 h, in order that equilibrium may be attained.

6.2 After equilibration of the coal, restore the pressure in the desiccator to atmospheric, with the desiccator still in the bath, by slowly admitting dry air for a period of not less than 15 min. Admit the air to the inlet tube of the desiccator after passing it through a train consisting first of a bubbler containing H_2SO_4 (sp gr 1.84), then a capillary tube with one end drawn out to a tip having a suitable bore for regulating the rate of air flow, and finally a coiled copper tube placed in the constant-temperature bath. Remove the desiccator from the bath and open immediately. Quickly close the weighing bottle, and weigh to the nearest 0.2 mg. Uncover the weighing bottle, place it in the moisture oven preheated to 105°C, and heat for 1½ h. Then remove the weighing bottle from the oven, cover, cool 30 min over H_2SO_4 (sp gr 1.84) in a desiccator, and weigh.

7. Report

7.1 Report the equilibrium or bed moisture to the nearest 0.1 percent as the percentage loss in weight of the equilibrated coal.

8. Reproducibility

8.1 The permissible differences between two or more determinations shall not exceed the following values:

Equilibrium Moisture, percent	Permissible Differences: Same Laboratory	Permissible Differences: Different Laboratories
Under 5	0.3	0.5
5 to 15	0.5	1.0
Over 15	1.0	1.5

[4] Holmes, J. A., "Sampling of Coal in the Mine," *Technical Paper No. 1*, U.S. Bureau of Mines XMBU A 1918.

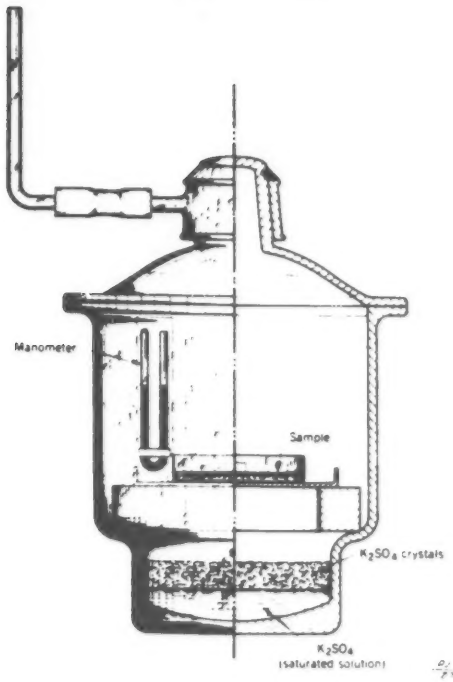

FIG. 1 Vacuum-Type Desiccator.

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